INTEGRATED CONCEPTUAL COST ESTIMATING AND LIFE CYCLE COSTING SYSTEM FOR BUILDING PROJECTS

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ABSTRACT

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Cost estimates are considered the most important and critical mission during the life cycle of a construction project. Preparing reliable and accurate estimates to help decision makers is the most challenging assignment that cost engineers and estimators can face. For decades, the construction industry focused on acquiring the construction costs of building facilities, neglecting the associated costs of running and maintaining them. Currently, by contrast, owners are interested in investigating the economics of facility management, which are the cost of owning and operating the building over its useful life.

This thesis presents a methodology that can be used for an integrated conceptual cost estimating and life-cycle costing system for building projects. The methodology describes the development and implementation of a system that automates the preparation of conceptual cost estimates and forecasts future costs of running building projects. This methodology does so by joining Computer Integrated Construction (CIC) and Virtual Reality Environment (VRE). The system integrates relational databases, a preliminary estimate module, an AutoCAD module, a global module, a cost estimate forecasting and decision support-system modules, and life-cycle costing and sensitivity analysis modules.

A modification in building design will result in an automatic generation of a new conceptual estimate. Subsequently, this modified drawing can be virtually animated and visualized by using a Virtual Reality browser. Finally, once capital costs are identified, the system forecasts the cost of running and maintaining the new building during its expected service life. Then, after assigning the range of deviation, it applies a sensitivity analysis method to investigate the most sensitive parameters so that further attention can be directed.

Designing the system in a user-friendly environment allows owners and decision makers to envision the feasibility of new building projects within their anticipated life cycle. Moreover, it assists architects and cost engineers to generate conceptual cost estimates in a dynamic environment. A numerical example is presented to illustrate the usefulness and capabilities of the developed system.

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ACRONYMS

BOMA: Building Owners and Managers Association

CAD: Computer Aided Drafting/Design

CIC: Computer Integrated Construction

CPI: Consumer Price Index

DBMS: Database Management System

DSS: Decision Support System

EAF: Expense Age Factor

ECF: Expense City Factor

EER: BOMA Experience Exchange Report

EHF: Expense Height Factor

ELF: Expense Location Factor

ESF: Expense Size Factor

IAF: Income Age Factor

ICF: Income City Factor

IFC: Industrial Foundation Classes

IHF: Income Height Factor

ILF: Income Location Factor

ISF: Income Size Factor

LCC: Life Cycle Costing

LCCA: Life Cycle Costing Analysis

MIS: Management Information System

NOI: Net Operating Income

NPV: Net Present value

O / M: Operating & Maintenance

O.C.D.I.: Own Cost Data Imperial

O.C.D.M.: Own Cost Data Metric

P.C.D.I.: Published Cost Data Imperial

P.C.D.M.: Published Cost Data Metric

PV: Present value

R.G.&S.: Road – Ground & Security Expenses

S. A.: Sensitivity Analysis

SIR: Saving / Investment Ratio

TNPV: Total Net Present value

TOEFEL: Total Operating Expenses plus Fixed Expenses plus Leasing costs

VB: Visual Basic

VBA: Visual Basic for Application

VRB: Virtual Reality Browser

VRE: Virtual Reality Environment

VRML: Virtual Reality Modeling Language

WBS: Work Breakdown Structure

CHAPTER ONE

INTRODUCTION

1.1 General

A construction project passes through many phases during its expected life starting with conception, passing into and through development, and continuing on to construction, to completion and occupying, and ending with disposing. During each of the first four phases, a new cost estimate has to be prepared depending on the availability of design drawings and specifications. It is during the initial phase that feasibility studies and conceptual cost estimates are most likely to be carried out. During this phase, it is the common practice for owners to acquire consultations from architects, and cost engineers about the cost of constructing a proposed project. Normally, at this stage, the cost estimate is based on the consultants' own experience, imagination, and wide range of assumptions and appraisals of similar projects previously constructed. The delivered opinion, which is documented either verbally or on paper, lacks considerable information about the construction cost, does not include the opportunity to visualize a prototype of the proposed project, and omits the future costs of running the facility over its anticipated service life.

Despite these deficiencies, feasibility studies and conceptual cost estimates play an important role in deciding whether a project could be realized based on the available budget.

Customarily, it is the attentiveness of owners and decision makers that is relied upon to control and to constrain the total construction costs of new buildings within their estimated values. Despite the increase in the cost of ownership and maintenance of these facilities, they are often not considered during the feasibility phase. This results in extra costs during the occupation of these facilities. Accordingly, additional data, efforts, and information are needed by the decision makers to realize these costs in their decision. Thus, the application of life cycle costing (LCC) has become one of the requirements of owners.

Management Information System (MIS) has enhanced many aspects of construction processes by storing the data and information concerning a project and by making them available, when they are needed, to all parties involved. However, implementing a reliable Management Information System depends on the modeling methodology followed in its design and on the reliability of the data involved.

The capability of such a system could be enhanced through the application of 3D-CAD modeling. This enhancement allows visualization of the project from any point in the workspace, thereby helping to eliminate design errors and to reduce costs. Such an improvement can be achieved by integrating different computer applications. This process is normally called Computer Integrated Construction (CIC). The integration process minimizes errors, secures data integrity, and improves the efficiency in the communication between participants concerned in designing and constructing a project. Furthermore, Virtual Reality Environment (VRE) users can animate and visualize 3D-CAD drawings by using a Virtual

Reality Browser (VRB). This procedure provides users with the option of viewing any building project in a real world setting before its existence occurs in reality. Consequently, this present research describes a methodology to establish conceptual cost estimates of a project, taking into consideration owning and operating costs. The methodology is implemented through the design and development of a system that automates the preparation of conceptual cost estimates of building projects and forecasts their running costs along their life cycle. The methodology puts an emphasis on integrating Life Cycle Costing, Management Information System, 3D-CAD modeling, Computer Integrated Construction, and Virtual Reality Environment, thereby providing a reliable tool to owners, architects, cost engineers, estimators and all participants involved in a construction project.

The methodology is incorporated in an integrated computer system capable of guiding users when performing feasibility studies for proposed projects. It also incorporates algorithms to execute necessary calculations in the following five modules: cost estimation, 3D CAD, parameter adjustment's calculations, Life Cycle Costing forecasting and sensitivity analysis, and decision support system and cost estimate forecasting. Each of the first four modules is linked to one or more databases containing the data and information necessary. On the other hand, the fifth module incorporates lists of linear regression equations that have been derived for forecasting the costs of facilities based on their size or budget entries. Numerous types of software used in the construction industry, such as

AutoCAD, 3D Studio, Microsoft Access, Microsoft Excel, and Visual Basic, were used in the development of this integrated system,

The successful implementation of such a system represents a significant advance in the ability to conduct feasibility studies during the early stages of proposed building projects, to generate conceptual cost estimates, and to predict the anticipated costs of owning and maintaining such projects.

1.2 Research Objectives

The main objective of this present research is to develop a methodology for conceptual cost estimate and life cycle costing for building projects at their pre-design stage.

The research sub-objectives are stated as follows:

1. Develop a methodology that effectively integrates the functions of cost estimating and life cycle costing. The integrated methodology is to minimize anticipated errors, reduce time and cost, and compose practical, efficient, and dependable feasibility study results.
2. Develop a methodology to automate accurate data retrieval from 3D CAD drawings and to export such data to external databases.
3. Identify required parameters and necessary adjustment factors that are considered when preparing parametric cost estimates. Accordingly, develop a model that automates the preparation of this type of estimate and executes all necessary adjustments. However in this thesis primary pre-designed composes these estimates:

4. Study the methods used in life cycle costing and their applications. Subsequently, develop a methodology to practically forecasts the running costs of new building projects within their anticipated life.
5. Incorporate these methodologies into an integrated prototype computer system to assist users in estimating conceptual costs and life cycle costing of a building during its feasibility stage.

1.3 Research Methodology

This present research aims at the development of an automated method for the preparation of conceptual cost estimates of new building projects. In order to meet the foregoing list of objectives the following procedures are carried out:

1.3.1 Literature Review

A comprehensive literature review is carried out in the areas of conceptual cost estimating, forecasting, life cycle costing, Management Information System, 3D-CAD Modeling, Computer Integrated Construction and Virtual Reality application in construction.

1.3.2 Interview

Twenty construction firms and practitioners have been contacted to get feedback and comments about developing the system, in addition to understanding both the problems they face at early stages of a construction project and the recommended solutions for them. Moreover, in pre-arranged presentations, the developed system has been shown and discussed at three different universities, one in Peoria, Illinois, another in Kalamazoo, Michigan, and a third in Toronto, Canada. Valuable comments and suggestions made during these presentations were accordingly taken into account in the system.

1.3.3 Data Collection

Data on thirteen actual high-rise building projects constructed in Canada and the USA have been collected from a well-known construction company in Vancouver. The company is an owner-builder firm that usually subcontracts the design of new projects to private consulting companies. The company uses its own cost data to conduct a quick feasibility study for new proposed projects. Since the gathered data is limited to one type of building projects, we are going to use the published data to overcome this gap. The data used in the system's development are based on R. S. Means Square Foot Costs and Assemblies Cost Data for building projects published in year 2000, and the BOMA publications from years 1984 to 1997, and Consumer Price Index (CPI) from year 1981 to 2002 published by Statistics Canada. Accordingly, the data from the actual projects are going to be applied in testing the performance of the developed system. An adjustment of the coding system is made to ease and simplify the process of adding, updating, editing, and modifying the cost data of the project.

1.3.4 Development of the System

Since the system integrates many applications, the development will be divided into the following five listed phases:

1. Designing all the relational cost databases needed to prepare parametric and preliminary cost estimates based on Masterformat and Assembly

Work Breakdown Structure (WBS), Life Cycle Costing (LCC) and sensitivity analysis, and 3D CAD drawing databases.

2. Designing internal AutoCAD modules.
3. Designing a global Visual Basic module to retrieve data and execute all required adjustments and calculations, and, furthermore, to virtually animate the modified project through a Virtual Reality Browser (VRB).
4. Designing and implementing a Life Cycle Costing module to forecast the costs of owning and maintaining proposed projects.
5. Deriving linear regression cost equations.

1.3.5 Experts Consultation

Once the system is developed, it will be presented to experts and practitioners for consultation, feedback, and criticism.

1.4 Thesis Organization

Chapter Two (Cost Estimate, a Background) introduces a summary of the comprehensive literature review. This includes: types, methods, and processes of construction cost estimates emphasizing on the parametric ones. In addition, this chapter includes the terminology, methods and cost categories of Life Cycle Costing and their applications, plus a brief description of forecasting techniques.

Chapter Three (Computer Applications in Construction) is a continuation of Chapter Two; it introduces a description of Database Management System and some of its application in construction. Likewise, it illustrates the role of 3D-CAD modeling and the advantages of its application in construction. In addition, it reviews the benefit of applying Computer Integrated Construction and the advantages of CIC to the construction industry.

Chapter Four (System Development Methodology) explains the methodology pursued in developing the system. The conceptual and logical designs of the system are discussed, which comprise:

a) The conceptual design of all the associated databases.

b) The system's architecture, components, and data flow.

c) The procedures used in the internal AutoCAD modules to calculate the area and perimeter of the building drawing.

d) The algorithm used in the global VB module to carry out required calculations. Besides the procedures utilized in forecasting the future costs and income of the facility as well as analyzing and identifying the most sensitive parameters in the sensitivity analysis module.

e) The procedures followed in applying linear regression method to derive all needed equations and in designing the decision support system.

Chapter Five (System Development Process) explains the progression of the integrated system. It describes the methodology employed in the system's components expansion, which includes the databases, AutoCAD internal modules, global VB module, forecasting and decision support system module and life cycle costing and sensitivity analysis module.

Chapter Six (System Performance) tests the effectiveness of the developed system through an actual case example. This case consists of a project executed in the city of Vancouver (B.C.) and includes preparing a parametric cost estimate for the project involved. Afterward, predicting the future costs of owning and maintaining the facility and its anticipated income, as well as analyzing the sensitivity of predefined sets of parameters to recognize the sensitive ones.

Chapter Seven (Conclusion, Limitations and Recommendations) includes an overview of the developed system based on the integration of the many applications involved in this research. The chapter also describes the research contributions and limitations and proposes recommendations for further enhancements and future expansions for the research.

Chapter Eight (References) lists the references involved in the literature review and methodology.

CHAPTER TWO

COST ESTIMATE, A BACKGROUND

2.1 Introduction

Cost estimates are essential procedures to be executed within the life of a construction project. The success or failure of a project depends on the level of accuracy of the estimated costs compared to the actual ones. The accuracy of the cost estimate is influenced by estimate type, method, and estimator experience besides the source and availability of cost data used in preparing the cost estimate and the project level of definition.

In the present environment, designers, cost engineers and estimators compete for limited economic resources so that optimum proposals are selected and implemented. The effective use of resources such as money, time, energy, and building materials is becoming a matter of extreme concern to all segments of the economic system. Hence, analyzing initial energy consumption, maintenance, and replacement costs has become a major requirement when evaluating total costs of new facilities. During feasibility studies for new building projects, this is an imperative for owners when they are determining the affordability of initial and associated follow-on costs. That necessity is recognized throughout the application of Life Cycle Costing Analysis and in the forecasting of all correlated costs.

Consequently, this chapter presents a review of the different types of cost estimates, of their levels of accuracy, methods, and application, focusing on the approximate ones. Moreover, it presents the terminology, methods, and cost categories of Life Cycle Costing and their applications, plus a short description of the forecasting techniques utilized in this area.

2.2 Construction Cost Estimate

Researchers and experts have defined construction cost estimates differently. The Association for the Advancement of Cost Engineering (AACE) International describes cost estimation as the basis for project management, business planning, budget preparation, and cost and schedule control. Included in these costs are assessments and evaluations of risks and uncertainties (Uppal 1997). On the other hand, the Project Management Institute (PMI) describes cost estimating as the development of an approximation (estimate) of costs of the resources needed to complete project activities (Duncan 1996). Forrest and Lorenzoni (1997) describe an estimate as being a prediction of the manner in which a project will be executed. The estimate basis should reflect a step-by-step plan of how the project people feel or predict the job will be done. Uppal (1999) also considers that cost estimation is the determination of quantity and the predicting or forecasting, within a defined scope, of the costs required to construct and equip a facility, to manufacture goods, or to furnish a service. Whereas, Peurifoy and Oberlender (2002) consider that estimating is not an exact science yet the knowledge of construction, common sense, and judgment are required. In conclusion, cost estimate is the means of forecasting and foreseeing the future costs of constructing a project before it actually exists. However, the final project cost will not be known until the construction is finished and the facility is operating.

2.3 Types of Cost Estimate

A project goes through different levels of estimates based on its development stage. Estimates are performed throughout the life of a project, beginning with the first estimate and extending through the various phases of design and into construction (Peurifoy and Oberlender, 2002). Forrest and Lorenzoni (1997) consider three basic stages or phases in project development, and for each of them, estimates are made:

1. The Planning/Evaluation stage includes *Screening; Preliminary; Quickie; Order-of-magnitude/Guesstimates; Rough, gross, scope, etc.*
2. Basic design stage includes *Preliminary; Budget; Semi-detailed.*
3. Detailed engineering construction stage includes *Definitive; Appropriation; Lump Sum; Detailed.*

Hendrickson (2000) believes that in spite of the many types of cost estimates used at different stages of a project, cost estimates can best be classified into three major categories according to their functions; these are the following:

- **Design Estimate,** for the owner or his/her designated design professionals, the types of cost estimates encountered run parallel with the planning and design as follows:

- Screening estimates (or order of magnitude estimates)
- Preliminary estimates (or conceptual estimates)
- Detailed estimates (or definitive estimates)
- Engineer's estimates based on plans and specifications

- **Bid Estimate,** for the contractor to submit to the owner either for competitive bidding or for negotiation. It consists of the direct construction cost including field supervision, plus a markup to cover general overhead and profits. The direct construction cost is derived from a combination of:
  - Subcontractor quotations
  - Quantity takeoffs
  - Construction procedures
- **Control Estimate,** for monitoring the project during construction. It is derived from available information to establish:
  - Budget estimate for financing.
  - Budgeted cost after contracting but prior to construction.
  - Estimated cost to completion during the progress of construction.

Whatever the project is, the type of its estimate may differ. The estimate is dependent upon available information, time demands, purpose of the estimate, and technique. The types of standard project cost estimating are the following: order-of-magnitude estimates, budget estimates, and definitive estimates. These three types of estimates are used to select the cost estimating technique with the appropriate level of accuracy (Vojinovic, Seidel and Kecman, 2000).

Derived from the foregoing types and classifications, the project's levels of definition, besides the availability of design data, establishes the type of the cost estimate. For this research, cost estimates can be divided into two kinds: those that are approximate and those that are detailed. Under which of these two, the listed types are included depends on the project stage.

2.4 Estimate Accuracy

Technically, if an estimate is poorly prepared very little can be done to improve it. Rast and Peterson (1999) indicate that accurate and consistent cost estimates are critical to any organization responsible for budget submission, contract negotiations, and financial decision-making. Such estimates are first developed at the order-of-magnitude level with an accuracy of +50 percent to –30 percent. They are later refined to the budget/conceptual level with an accuracy of +30 percent to –15 percent and the definitive level with an accuracy of +15 percent to –5 percent. On the other hand, AACE International grouped cost estimating into five classes depending on the level of the project's definition and purpose as shown in Table 2.1 (Peurifoy and Oberlender, 2002).

Table 2.1: AACE International Cost Estimation Classifications (18R-97)

Estimate Class	Level of project definition	End usage- Typical purpose of estimate	Expected accuracy range
Class 5	0% to 2%	Concept screening	-50% to 100%
Class 4	1% to 5%	Study or feasibility	-30% to +50%
Class 3	10% to 40%	Budget, authorization or control	-20% to +30%
Class 2	30% to 70%	Control or bid/tender	-15% to +20%
Class 1	50% to 100%	Check estimate or bid/tender	-10% to +15%

Oberlender and Trost (2001) consider that the accuracy of an estimate is measured by how well the estimated cost compares to the actual total installed cost. The accuracy of an estimate depends on four factors: (1) who was involved in preparing the estimate; (2) how the estimate was prepared; (3) what was known about the project; and (4) other factors considered while preparing the estimate. Park, Choi and Kim (1999) believe that, since no particular rules of measurement for building elements exist in the industry, the reliability and accuracy of the estimate in the preliminary design phase is greatly dependent on the experience of individual cost estimators.

Consequently, the accuracy, reliability, and quality of an estimate are significant despite its type. It is obvious that the estimator's experience and the amount and characteristics of the information and data available and the time spent in preparing the estimate do control its accuracy.

2.5 Approximate Estimates

Approximate estimates known also as Parametric, Order of Magnitude, Screening, Conceptual, Budget, Pre-design, Pre-construction, and Preliminary are normally prepared by owners, designers and cost engineers at early phases of a construction project. However, parametric estimates are mainly generated at the conceiving stage of a construction project where the level of definition is not yet identified. On the other hand, preliminary estimates are prepared where up to 40% of the conceptual design is available and the project is better defined. In some circumstances, contractors use them for quick reference depending on the project type, size, and completion time. Owners and engineers utilize these estimates to screen and eliminate unsound proposals without extensive engineering costs. Approximate estimates are sufficiently accurate for the evaluation of design alternatives or the presentation of preliminary construction estimates to the owner, but are not sufficiently accurate for bid purposes (Peurifoy and Oberlender, 2002). Likewise, Forrest and Lorenzoni (1997) state that a Screening estimate is the earliest of estimates and is made to enable the user to decide which way to go on with a project. Management usually requires this estimate to select the proper route for the next step in developing the project. This present research is based on two types, which are Parametric and Preliminary estimates, with emphasis on the first.

2.5.1 Parametric Estimates

This type of estimate is used by owners at the initial phase of a project to generate an understanding about the costs of converting an idea to reality. Such an estimate is made prior to the availability of a project's plans and specifications. The Order-of-Magnitude cost estimating is defined as a quick method of determining an approximate probable cost of a project without the benefit of detailed scope definition (Simpson, 2000). Similarly, Hendrickson (2000) asserts that a Screening or Order-of-Magnitude estimate is usually made before the facility is designed, and must therefore rely on the cost data of similar facilities built in the past. On the other hand, Moselhi and Siqueira (1998) mention that individual estimating experience and different estimating practices, especially in Order-of-Magnitude and Parametric estimating, lead to high levels of inconsistency. Alternatively, Bajaj, Gransberg and Grenz (2002) judge Parametric estimating as being quite accurate if the historical data are properly captured from the source. Moreover, Meyer and Burns (1999) consider that Parametric cost estimating uses factors based on engineering parameters to develop accurate cost estimates. These engineering parameters are developed from historical cost databases, construction practices, and engineering/construction technology whereas Bajaj, Gransberg and Grenz (2002) consider that Parametric estimation is effectively used by the construction industry, and its main application to reduce the time involved in bidding on a job. Parametric estimating is used to generate detail for the early budget stages of design when there is no formal design drawn on paper. However, one must first have a few available parameters and cost data for a completed project that is similar in scope to that of the new design (Melin, 1994). Furthermore, Ellsworth (1998) believes that the simplest method to establish the reasonableness of facility costs is to identify the costs of similar projects and compare these costs with the cost of the new facility. Nevertheless, in many instances, cost information is unavailable for facilities of comparable size, so facilities significantly different in size may have to be considered when developing cost estimates. The parametric approach to cost estimating is a procedure involving the use of a constant parameter (with variable values) as a reference for other variables (Melin, 1994). The parameters from which Parametric cost estimates derive include physical properties that describe project definition characteristics such as size, building type, foundation type, exterior closure materials, roof type and material, number of floors, functional space and utility system requirements (Meyer and Burns, 1999).

2.5.1.1 Modeling Parametric Estimates

Dysert (1999) indicates that a Parametric cost model is an extremely useful tool for preparing early conceptual estimates, when there is little technical data, or engineering deliverables to provide a basis for using more detailed estimating methods. Moreover, Meyer and Burns (1999) mention that the use of the Parametric models helps to avoid the errors and omissions that are common in traditional cost estimating procedures, particularly during planning and early design phases. The data models used in the preparation of a parametric estimate are essential to the process. Before a parametric estimate can be generated, estimate data models must be created, because the model's basic requirements are based on quantitative takeoffs of past estimated projects (Melin, 1994). Using a Parametric cost estimating model to prepare cost estimates provides the detail and accuracy of manual estimates, but is 10 times faster, less error-prone, and 20 times more efficient in comparing alternatives (Rast and Peterson, 1999). Dysert (1999) divides the process of developing a Parametric cost estimate model into the following steps:

- Cost model scope determination,
- Data collection,
- Data normalization,
- Data analysis,
- Data application,

- Testing,
- Documentation,

Therefore, modeling the Parametric cost estimates preparation requires that specific techniques and methods be followed in order to improve the accuracy and reliability of that estimate as explained in the subsequent paragraph.

2.5.1.2 Parametric Estimate: Methods and Techniques

Bajaj, et al. (2002) conclude that in order to use parametric estimation techniques in an effective manner, it is necessary to do the following:

- Have an effective cost accounting system,
- Prepare a database from the accounting history,
- Identify the different multipliers required to normalize the data (location factors, inflation factors, and project type factors),
- Exclude outliers,
- Do statistical analysis to find cost estimating relationships,
- Apply required multipliers,
- Prepare a template,

The most basic method is to identify the intended scope of the project, for buildings this would be measured in gross square feet and referred as the "square foot" method. This method generally has an accuracy of ± 20 percent; this is supported by the R. S. Means Estimating Handbook (Larson 2002). Furthermore, Karshenas, (1984) mentions that one of the most common methods used in approximate estimates is the square-foot method. In it, historical building cost data or cost books are used to get an estimate of the cost per square foot of the type of building under consideration. The estimated unit cost is then multiplied by the gross floor area of the proposed building after being adjusted for factors as location, size, and the expected quality of the proposed building. Meyer and Burns (1999) classify the required parameters to include:

- Building area,
- Number of building stories above grade,
- Number of building stories below grade,

And the optional parameters as:

- Density Parameters include: doors (EA); wall finishes (SF); partitions (SF); plumbing fixtures (EA)
- Quantity Parameter include: perimeter (LF.); roof area (SF); floor to floor height above grade (FT); exterior wall area (SF); exterior doors (EA)
- Descriptive Parameters include: floor structure; roof structure; roof type; exterior wall type; stair type

Whereas, Bajaj, Gransberg and Grenz, (2002) acknowledge that if the historical data are present and are normalized for multipliers, like inflation factors and location factors, they can be effectively used to bid on a job in considerably less time. Dysert (1999) lists the data that normalization implies making adjustments for:

- Escalation,
- General location,
- Site conditions,
- System specifications,

- Cost scope,

Therefore, besides the methods, parameters and the historical data used, modeling the process of Parametric estimates is a prime requirement for the preparation of a liable and accurate estimate.

In this research, the process of preparing Parametric cost estimates in both units imperial and metric is to be modeled on and based on R. S. Means square foot cost data having Assembly as the work breakdown structure. The parameters used consist of the following: building area, building perimeter, floor area, number of floors, floor to floor height, exterior wall type, floor and roof structure. The utilized data is to be normalized for: location, inflation, size, height, and exterior wall and structure type.

a) Adjustment for Location

Brown and Hajdaj (2001) define a construction cost index as being a tool to measure the cost increases of construction labor and materials. A good cost index can also be used to adjust previous bids and cost estimates to the present time and to project their future costs for from 1 to 20 years, based on past cost increases and experience. Barrie and Paulson (1992) state that cost indices show changes in cost over time. Generally, they are applied to the construction phase of projects. Cost indices are a measure of cost escalation and are used to project cost data from one time to another (Westney, 1997). Similarly, Adrian (1993) describes a cost index as providing a comparison of cost or price changes from year to year for a fixed quantity of work or services. It enables the estimator to forecast the cost of a similar type of work from the past to the present or future period without going through detailed costing, whereas, Forrest and Lorenzoni (1997) believe that the mechanism for converting standard costs to present-day costs at a given location is accomplished by means of cost indexes. These indexes are factors representing a comparison or cost ratio between the latest cost data available and the equivalent standard cost data. Cost Engineers analyze the feedback data and arrive at an average ratio, which is called a location cost index. Furthermore, Dawood and Bates (1997) state that, to develop the index, there is one main requirement: the historical data. Without the data, there can be no index creation. It has been said that the future lies in the past. In addition, Pietlock (1995) identifies a location factor as being used during preliminary project evaluations. They provide a means of evaluating relative cost differences between two geographical locations. They are often applied to conceptual estimates for identifying "go/no-go" projects at an early stage. Furthermore, Peurifoy and Oberlender (2002) consider that the use of cost information from a previous project to forecast the cost of a proposed project will not be reliable unless an adjustment is made that represents the difference in cost between the locations of the two projects.

Cost indices can be found in different sources, including:

- *Engineering News Record (ENR) Index:* This is the oldest index in current use. It is published in the *Engineering News Record* magazine. It is weighted towards the general construction industry (Westney, 1997). ENR publishes two indices that are Building Cost Index (BCI) and Construction Cost Index (CCI). They both measure the effects of wage rate and material price trends, but they are not adjusted for productivity, efficiency, competitive conditions, or technology changes. Consequently, all these indices measure only the price changes of respective construction *input factors* as represented by constant quantities of material and/or labor (Hendrickson, 2000).

- *Means City Cost Index:* This is another useful tool to use when comparing costs from city to city and region to region published by R. S. Means. This publication contains average construction cost indexes for 689 U.S. and Canadian cities. It is a percentage ratio of a specific city's cost to the national average cost of the same item at a stated period. These index figures represent relative construction factors for Material and Installation costs, as well as the weighted average for Total in Place costs for each Masterformat division. Installation costs include both labor and equipment rental costs. The 30 City Average Index is the average of 30 major U.S. cities and serves as a National Average. The index value does not include productivity variations between trades or cities, managerial efficiency, competitive conditions, automation, restrictive union practices, owner's unique requirements, and regional variations due to specific building codes (R. S. Means Building Construction Cost data, 2000).

- *Marshall and Swift:* This index traces equipment costs and installation labor in selected process industries and in related industries. It therefore reflects changes in installed equipment costs. It is published in *Chemical Engineering* Magazine.

- *Chemical Engineering Plant Cost Index:* This is a special purpose index published in *Chemical Engineering* magazine and weighted by the chemical process industry cost experience for equipment, machinery and supports, construction labor, buildings, and engineering and supervision.

- <u>*Nelson Refinery Construction Index:*</u> This index is heavily weighted towards the refinery and petrochemical segments of the Consumer Price Index. It is an inflation index that shows the relative cost of duplicating an installation without respect to mechanical or process design, construction techniques, size, or changes in technology (Westney, 1997).

This present research uses the historical City Cost Index Data published by R. S. Means, with the emphasis that the objectives of this research lie in using the indices' value as published regardless of their calculation's methods. Equation (2.1) is to be used to adjust the previous projects cost data for the City Cost Index.

$$C_A = C_N \left(\frac{I_A}{I_N} \right) \qquad [2.1]$$

Where C_A = cost in dollars for city A

C_N = national average cost in dollars

I_A = index for city A

I_N = index based on the 30 major city average of 100

b) Adjustment for Time (Inflation)

The term *"inflation"* implies that there is a tendency for all prices in the economy to be rising, while the term *"escalation"* on the other hand is an all-inclusive term that reflects price increases due to any number of causes, such as inflation, supply and demand conditions, or environmental issues (Westney, 1997). NASA (2002) defines the inflation rate as the percentage change in the price of an identical item from one period to another. Likewise, Peurifoy and Oberlender (2002) believe that the use of cost information from a previous project to forecast the cost of a proposed project will not be reliable unless an adjustment is made proportional to the difference in time between the two projects. This adjustment should represent the relative inflation or deflation of costs with respect to factors such as labor rates, material costs, and interest rates, etc. Furthermore, Pietlock (1995) considers that a location factor developed from data supplied last year would have to be adjusted for currency and inflation differences between the two countries before it could be used today. Similarly, Uppal (1999) identifies escalation as the provision in actual or estimated costs for an increase in the cost of equipment, material, labor, etc., over that specified in the purchase order or contract, due to continuing price level changes over time. Likewise, NASA (2002) classifies the use of inflation indices for: 1) Inflating cost model results expressed in terms of constant year costs to real year dollars for budgetary or program operating plan purposes. 2) Converting from constant dollars expressed in one year to constant dollars expressed in a different year, and 3) Normalizing historical cost data expressed in real-year dollars to constant-year dollars.

Peurifoy and Oberlender (2002) derived equation (2.2), which uses the change in value of an index between two years, to calculate an equivalent interest rate.

$$\left(\frac{I_{Current}}{I_{Reference}}\right) = (1 + i)^n \qquad [2.2]$$

Where n = number of years between current and reference year

$I_{Current}$ = index for current year

$I_{Reference}$ = index for reference year

i = equivalent interest rate

That equivalent interest rate can be used to adjust past cost records to forecast future project costs by using equation (2.3).

$$F = P\,(1 + i)^{n} \qquad [2.3]$$

Where n = number of years between known and forecasted year

F = forecasted cost of the proposed project

P = past cost of completed project

Nonetheless, in this research the user will enter the value of the equivalent interest rate.

c) Adjustment for Size

The use of cost information from a previous project to forecast the cost of future projects has to be adjusted for the difference in size between two projects (Peurifoy and Oberlender, 2002). The aim of this research is to automate the process of adjusting the proposed project size using the square foot project size modifier provided by Means Square Foot Costs (R. S. Means, 2000).

d) Adjustment for Height, Exterior Wall and Structure Type

Based on the classification given by Meyer and Burns (1999) these adjustments are for optional parameters. Using such parameters can enhance the accuracy and efficiency of the proposed system. Tan (1999) considers that tall buildings are invariably more expensive to build than two or three storey buildings offering the same accommodation, and the taller the building the greater the comparative cost. This is due to a number of factors: the special arrangements to service the building, particularly the upper floors; the necessity for the lower part of the building to be designed to carry the weight of the upper floor; the cost of working at great height from the ground when erecting the building; the increasing area occupied by the service core of the circulation. Whereas, Picken and Ilozor (2003) believe that conventional wisdom in the construction industry suggests that for the same areas of accommodation, tall buildings are more expensive to construct than low-rise buildings. Generally the cost of building per square meter of floor area can be expected to increase with the addition of extra floors; tall buildings are invariably more expensive to build than two or three storey buildings offering the same accommodation. For this present research, the cost variation due to the fluctuation of floor height is implicit and based on criteria set by R. S. Means. Therefore, the adjustments for these parameters are established using R. S. Means Cost Data depending on the building type and gross area. These adjustments are better explained in chapter four, which deals with the research methodology.

2.5.2 Preliminary Estimates

Project designers are required by owners to supply a preliminary cost estimate of the proposed project that is revised throughout the design phase proportionally with the level of definition. Using AACE's classification (table 2.1), this type, known as a pre-construction estimate, is a class 3 estimate where the level of definition is up to 40%. The purpose of a preliminary estimate can vary depending on the owner's demands and the type and size of the project. Adrian (1993) thinks that a preliminary estimate is made without working drawings or detailed specifications. The estimator has to make such an estimate from rough design sketches, without dimensions or details, and from an outline specification. Vojinovic, et al. (2000) consider that preliminary estimates are normally used for long-term capital expenditure programs and for the initial evaluation of the projects when there is a lack of detailed information. Whereas, Johnson and Kwong (2001) state that in predesign, estimating time and resource limitations often preclude efforts at adequately defining and documenting system scopes. They are defining "predesign estimating" as estimates prepared during the pre-schematic design phase. Ostwald (1984) defines a preliminary estimate as one that is made in the formative stages of design. Overlooked in this definition is the accuracy, type of design evaluated, and the purpose of the estimate. Uppal (1999) believes that preliminary estimates for capital expenditure projects are a basic requirement for a company's strategic planning. On the other hand, Sanders, Maxwell, and Glagola (1992) believe that too often funding decisions are made based on inadequate preliminary estimates.

Therefore, despite their level of accuracy, these types of estimates are considered to be the management key for dismissing or continuing a proposed project. In this present research, the preparation of preliminary estimates is to be modeled on and based on R. S. Means Cost Data following both the Masterformat and Assembly work breakdown structure in both imperial and metric units.

2.6 Life Cycle Costing

The determination of costs is an essential part of the construction process and a considerable element of the tools used by decision makers. Presently, there is a growing demand to achieve better outcomes from a facility throughout its anticipated service life. Hence, maintenance and operating costs should be involved because they consume considerable resources over the lifespan of that facility. Accordingly, both capital and running costs have to be taken into account whenever construction management decisions involving costs are made. The concept of life cycle costing (LCC) has evolved as a result. Abraham and Dickson (1998) believe that life cycle costing studies show that the cost of owning and operating a system (ownership cost) can be quite significant and may often exceed acquisition costs. Thus, decisions based solely on acquisition cost may not turn out to be the best selection in the long term.

There is some literature that focuses on life cycle costing, yet few researchers and practitioners give a clear definition of LCC. For instance, Fuller and Petersen (1996) define LCC as the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system over a period of time. Furthermore, they define LCCA as an economic evaluation technique that determines the total cost of owning and operating a facility over its assumed life. Similarly, the Royal Institution of Chartered Surveyors (RICS) defines the life cycle cost of an asset as the present value of the total cost of that asset over its operating life (including initial capital cost, occupation costs, operating costs and the cost or benefit of the eventual disposal of the asset at the end of its life).

Additionally, it defines LCCA as a set of techniques for evaluating all relevant costs of acquiring and operating a project, asset, or product over time. Moreover, NSW Department of Public Works and Services Cataloguing-in-Publication data, Sydney (2001), defines the LCC of an asset as the total cost throughout its life including planning, designing, acquisition and support costs and any other costs directly attributed to owning and using that asset. Further, Dell'Isola and Kirk (1995) consider that, basically, LCC is an economic assessment of an item, area, system, or facility, considering all the significant costs of ownership over its economic life expressed in terms of equivalent dollars. Similarly, Assaf et al. (2002) define the LCC as the economic assessment of alternative designs, construction or other investments considering all significant costs of ownership and running over the economic life of each alternative expressed in equivalent economic units.

The present research considers life-cycle costing analysis (LCCA) as a process of evaluating the feasibility of a new project taking into account all involved costs starting from initial to disposal. Figure 2.1 illustrates the phases that a construction project passes through in its life cycle.

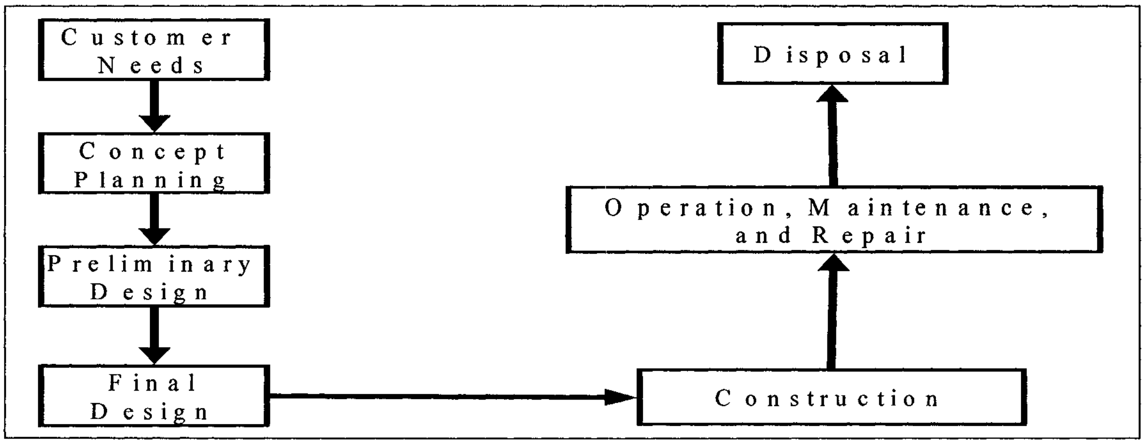


Figure 2.1 Project's Phases during its Life Cycle.

2.7 Terminology of Life Cycle Cost Analysis

Life Cycle Cost Analysis (LCCA) is an essential design process for controlling the initial and future costs of owning a building. LCCA can be implemented at any level of the design process and can be used effectively as a tool to evaluate the systems of an existing building. The Life Cycle Costing equation comprises the following three variables: the pertinent **costs** of ownership, the **study** period over which these costs are incurred, and the **discount rate** that is applied to future costs to equate them with present day values. Fuller and Peterson (1996) consider the LCC method of economic analysis as the basic building block of LCCA. This method is used to compute the total cost of owning, operating, maintaining, and disposing of the building system over a given study period (usually related to the life of the project). All these costs are adjusted (discounted) to reflect the time-value of money.

2.7.1 Costs

Al-Hajj and Horner (1998) define the costs' components included in LCCA as follow:

- ***Maintenance Costs*** are the costs of keeping the building in good repair and working condition. This includes painting, decorating, repairs, and renewals.
- ***Operating Costs*** are the costs associated with operating the building itself; they include the cost of cleaning, energy and security.
- ***Running Costs*** are the sum of maintenance and operating costs.

Figure 2.2 illustrates a detailed classification of all the associated income and expenses considered in LCCA after Zhang (1999).

Capital Costs	O/M	Replacement	Income	Salvage
Land Purchase	**Operating Cost**	Periodic Replacement	***Rental***	***Resale Value***
	Energy	Roof	***Retail***	
Acquisition Fee	Electricity	Exterior Wall Painting	***Parking***	***Scrap Value***
Commissioning	Gas	HVAC		
Professional Fee	Fuel-Oil	Wages / Supplies	***Others***	
Architect/Engineer	***Cleaning***			
Lawyer	***Security/Administration***			
	Wages / Supplies			
Construction Cost	Legal Fees			
Site	Office Expenses			
Structural				
Electrical	***Leasing Expense***			
Mechanical	***Fixed Expense***			
	Real Estate Tax			
Promotion & Sales	Building Insurance			
Funding Cost	**Maintenance Cost**			
	Elevator			
Management Cost	HVAC			
	Electrical			
	Structure			
	Plumbing			
	Fire Equipment			
	Wages / Supplies			

Figure 2.2 Income and Expenses Categories *(Zhang, 1999)*

On the other hand, the State of Alaska (1999) classifies future costs into two categories:

- ***Recurring Costs*** are those costs that occur every year over the span of the study period. Most operating and maintenance costs are recurring costs. Usually, these costs are expressed as annual expenses incurred at the end of each year.
- ***One-Time Costs*** are the costs that do not occur every year over the span of the study period. Most replacement costs are one-time costs. They are incurred at the end of the year in which they occur.

2.7.2 Study Period

The State of Alaska (1999) defines the study period as the period of time over which ownership and operations expenses are to be evaluated. Typically, the study period can range from twenty to forty years, depending on the owner's preferences, the stability of the user's program, and the intended overall life of the facility. Fuller and Petersen (1995) further consider the study period for LCCA as the time over which these costs and benefits related to a capital investment decision are of interest to the investor. Since different investors have different time perspectives with regard to capital investment projects, there is no one correct study period for a project. However the same study period must be used in computing the LCC of each project alternative being compared for a given purpose. ***Study period*** starts with the base date that includes the planning and construction period and the ***service period*** or beneficial occupancy period.

2.7.3 Discount Rate

The discount rate is "the rate of interest reflecting the investor's time value of money". Basically, it is the interest rate that would make an investor indifferent as to whether he will receive a payment now or a greater payment at some time in the future (The State of Alaska, 1999). Furthermore, Fuller and Petersen (1995) separate the discount rate into two types:

- ***Real Discount Rate:*** is the rate that excludes the rate of inflation and is used with constant-dollar amounts
- ***Nominal Discount Rate:*** is the rate that includes the rate of inflation and is used with current-dollar amounts.

However, the discounting formula used to convert future costs to present value is:

$$P = F\,(1 + i)^{-n} \qquad [2.4]$$

Where n = number of years compromising the study period

F = Future Costs

P = Present value

i = Discount Rate (either Real or Nominal)

The State of Alaska (1999) defines **Constant Dollars** as "dollars of uniform purchasing power tied to a reference year and exclusive of general price inflation or deflation." By contrast, it defines **Current Dollars** as "dollars of non-uniform purchasing power, including general price of inflation or deflation, in which actual prices are stated."

2.8 Modeling Life Cycle Costs

Dell'Isola and Kirk (1995) consider that a common methodology for LCC, when dealing with Architecture/Engineering (A/E) systems such as buildings, includes:

- Identification of significant costs for each alternative
- Summation of costs per year
- Discounting the costs back to a common base
- Selecting the lowest cost alternative
- Evaluating the final selection with additional non-economic consideration

Alternatively, Dhillon (1989) identifies two categories of LCC models; General and Specific

a. General models that address a broad topic and provide a structure or framework to the costing approach by identifying the phases in the life of the facility and the costs associated with each phase. This type of model might be used for the initial LCC Analysis

b. Once the application is well defined, the general model has to be reformed and essentially becomes a Specific life cycle model

Whereas the NSW, Sydney (2001) considers that a life cycle costing model is essentially an accounting structure containing terms and factors that enable estimation of an asset's component costs. Despite the availability of many commercial models that can be used for LCC Analysis, in most cases it is appropriate to develop a model for specific application. In either case, LCC models should:

- Represent the characteristics of the assets being analyzed including their intended use environment, maintenance concept, operating and maintenance support scenarios, and any constraints or limitations
- Be comprehensive enough to include and highlight the factors relevant to the asset LCC
- Be easily understood to allow timely decision-making, future updates and modification
- Provide for the evaluation of specific LCC elements independently of other elements.

These models should also be reviewed with respect to the applicability of all cost factors, empirical relationships, constants, elements, and variables.

2.9 Life Cycle Costing Application Problems

Applying the LCC approach for any facility is not an easy task for cost engineers and estimators. Many problems arise depending on the facility type and the owner's needs. Assaf et al. (2002) have drawn up five categories of problems, which include:

- ***Knowledge Problems*** **-** the components in this category are:
  - Unfamiliarity with the design-to-cost concept;
  - Lack of knowledge of the concept;
  - Existence of an unknown relationship between initial and future cost
  - Unavailability of enough references
- ***Data Problems*** **-** life cycle costing is heavily dependent on data. The data used should be derived from previously executed projects and should include all types of data, such as cost, performance, occupancy, and general description information. In collecting and analyzing the data, the designer will face many problems, including the following:
  - Unavailability of capital cost data;
  - Unavailability of maintenance data;
  - Unavailability of operation data
  - Unavailability of discount or interest rate data
  - Unavailability of life time data
  - Large volume of data needed
  - Unavailability of a standard method for collecting and recording data

- Unavailability of a Database Management System

- ***Procedures Problems*** - this type of problem includes the following:
  - Unreliability of decision taken
  - Lack of integrity of forecast
  - A majority of life cycle costing calculations involve uncertainty
  - Unavailability of qualified staff
  - Unavailability of qualified consultants
- ***Management Problems*** - this type of problem includes the following:
  - Concept Un-acceptance
  - Government non-enforcement
  - Management (client) pressure to meet budget limits
  - Unclear benefits of life cycle costing to management (client)
  - Improper planning and control of management tasks at different life cycle costing stages
- ***Cost Problems*** - this type of problem includes the following:
  - Cost paid for engineers to conduct life cycle costing
  - Cost paid for collecting data
  - Difficulties in defining cost elements

Appendix (A) provides detailed explanations for each of the foregoing categories and their associated elements.

2.10 Forecast and Forecasting

Griggs (2002) considers that the most difficult and misunderstood task on a project is the function of forecasting. The term "forecast" has several meanings. For instance, it is to plan ahead of time, to foresee and to calculate beforehand. Park and Jackson (1984) think that forecasting requires some sort of predictive models or techniques that can use today's data. After all, if those data are correct and valid, the conclusions will be accurate. Whoever is involved in the economic evaluation of engineering projects forecasts three broad types of future conditions. Those types of conditions are the following:

- Economic Conditions refer to the nation's aggregate economy without particular reference to any specific industry. The Gross Domestic Product (GDP) is probably the most important single indicator of general economic conditions.
- Technological Conditions encompass a variety of factors affecting the development of new products, processes, and markets.
- Business Conditions take into account the specific factors of price, cost, and volume, which ultimately determine the profitability of a given industry, company, or venture.

However, the first step in forecasting is to collect the appropriate data. The most common sources of economic data include government agencies, trade associations, and business publications. Therefore, the present research uses both government (CPI) and business (BOMA) publications to forecast the projected costs and incomes of building projects when applying LCCA. Detailed explanations for this matter are given in chapter four.

2.11 Summary

This chapter has reviewed previous theories and practical works related to construction cost estimates. This literature review reveals that parametric and preliminary estimates are vital for owners and management when deciding on the future of a construction project. Modeling the preparation of these estimates is advantageous particularly when explicit methods and techniques are followed to normalize the pertained parameters. Furthermore, a brief review of the importance of applying Life Cycle Costing Analysis for construction projects is illustrated. It describes the involved elements that have to be considered when conducting this type of study of new projects. Additionally, the review lists not only the most common components and steps followed during the study but also the application problems that might occur when it takes place. Moreover, a concise explanation of forecasting requirements and conditions was addressed.

CHAPTER THREE

COMPUTER APPLICATIONS IN CONSTRUCTION

3.1 Introduction

The use of computers to generate cost estimates including life cycle costing, and to integrate all aspects of construction measures has improved efficiencies and reduced time and costs. However, the availability of historical stored data is very significant if one wishes to obtain the best outcomes. That can be done by employing Management Information System through the application of relational databases. Nonetheless, in the construction of a project, the participants, who come from different firms, fields and areas of design and construction, are separate entities. During the project, they all combine their efforts; experiences, practices, and construction methods to accomplish a job and, once it is completed, they may disperse and may never meet again. During this process, the lack of interrelated information between all parties is anticipated. This lack increases errors and consumes time and costs. When the project is underway, there are considerable efforts to integrate multiple software applications to better support engineering and construction analysis and operations.

Accordingly, this chapter reviews the general use of Management Information System through database applications in the construction industry and in particular its use in establishing cost estimates and life cycle costing. Additionally, it investigates the positive impact on this industry of employing 3D-

CAD modeling, especially when integrated with databases. Likewise, it focuses on the application of Computer Integrated Construction (CIC) and its ability to improve construction practices by increasing efficiency, by narrowing the lack of information between parties, by minimizing emissions and errors, and by increasing the involvement of all the participants in the project.

3.2 Management Information System

The availability of historical data is indispensable for the preparation of cost estimates. Nonetheless, this data has to be properly organized and convenient for the cost engineers and estimators to manipulate, edit, and modify according to the project estimates needs. This is done by applying Management Information System through Relational Databases. Whitten and Bentley (1998) define Management Information System (MIS) as being an information system application that provides for management-oriented reporting, usually in a predetermined and fixed format. MIS can present detailed information, summary information, and exception information. On the other hand, Hegazy (1993) defines MIS as a computer system capable of integrating data from many sources to provide data and information useful to support operations and decision-making. Management Information is normally produced from a shared database that stores data from many sources. Thus data analysis and database design become critical to MIS design (Whitten and Bentley, 1998). Databases and database technology are having a major impact on the growing use of computers. It is fair to say that databases will play a critical role in almost all areas where computers are used (Elmasri and Navathe, 2001). Decker, Oaks and Salinas (1997) define a data warehouse (database) as a repository of data collected by systems and processes already in place. It is not unusual when building a data warehouse to discover the need for additional operational data that have not been systematically collected. A database is a collection of interrelated stored data that serves the needs of multiple users within one or more organizations, that is, interrelated collections of many different types of tables (Teorey, 1994); (Elmasri and Navathe, 2001); (Whitten and Bentley, 1998). Moreover, Durvel and Schmidt (2002) state that a database is a collection of tables, queries, forms, and reports. While, Spainhour and Rasdorf (1996) state that a good database implementation depends on how accurately and completely the data involved in the domain can be modeled. One way to ensure the development of a good data model is by using a formal modeling methodology that enables a database schema to be designed in a systematic fashion. Whitten and Bentley (1998) describe data modeling as a technique for organizing and documenting a system's data, whereas, Elmasri and Navathe (2001) consider a data model as a set of concepts that can be used to describe the structure of a database. This set includes the data types, relationships, and constraints that should hold for the data. On the other hand, Loucopoulos and Zicari (1992) proclaim that a consistent information system depends on the integration between databases, programming languages, and software engineering; its lifecycle incorporates the interrelated technologies of conceptual modeling and database design. Spainhour and Rasdorf (1996) think that modeling the functional application requirements and information system components at a conceptual level is important, given the growing demand for information systems of ever-increasing size, scope, and complexity. Aouad et al. (1995) deem that the conceptual modeling of construction management information models the information for the activities performed at the post design stage. The resulting conceptual models form the basis for developing construction management databases, which can monitor time, cost and quality aspects of a construction project. Al-Hussein (1999) thinks that different database structures are available, such as, hierarchical and networked, which represent data and data interrelation using predefined structures. Such database structures are difficult to modify. Therefore, relational databases are widely used; they allow data modeling using simple structures (tables) without having to predefine the data interrelations. On the other hand, Kibert and Hollister (1994) suppose a relational database is characterized by its simplicity of data management, by the independence of logical user views from the physical data storage structure, and by the availability of simple but powerful relational operators. These characteristics translate into a collection of tables that are composed of rows and columns. Whitten and Bentley (1998) state there are several notations for data modeling. The actual model is frequently called an Entity-Relationship Diagram (ERD) because it depicts data in terms of the entities and relationships described by the data. Entity-Relationship (ER) models are frequently used for the conceptual design of database applications. The (ER) model describes data as entities, relationships, and attributes. Entities and relationships are appropriate for representing design information (Elmasri and Navathe, 2001).

The data stored in the relational database can be accessed and queried by using a language named Structure Query Language (SQL). SQL is a language that controls user access by specifying security constraints. It allows sophisticated data management processes to be performed on databases that are based upon highly orthogonal yet simple principles (Kibert and Hollister, 1994).

Therefore, this research will employ the foregoing techniques in designing and implementing the required cost databases. The design processes commence with conceptual-to-physical modeling and ending by data mapping and entering. The design and development steps are explained in detail in chapter four.

3.3 3D-CAD Modeling

Nowadays, many industries are using Computer-Aided Design (CAD) systems in their engineering and design processes. AutoCAD is considered the most popular application applied in the construction industry. Many research works have been conducted in modeling the design procedure of all aspects of construction through the application of 3D-CAD modeling. For instance, Diez, et al. (2000) developed a system called AUTOMOD3 for the automatic design of modular building. The system is focused on the design stage; it adapts and links the methods of traditional architectural design with new construction methods. They calculate the 3D modules and 2D panels needed to construct a block of flats; afterward, these will be pre-fabricated in a factory and then transported to the site for their automatic assembly. For reinforced concrete structures, Kunigahalli (1997) presents a 3D geometric modeling scheme that takes into account the reinforcement detail for rectangular/square columns designed using one-way and two-way slab theories. Euler (1994) introduces an approach to reducing construction costs that is based on using the 3D CAD plant model on the job. Data built into the 3D CAD plant model during design are enhanced and used as a construction management tool. That procedure extends the useful life of the 3D CAD plant model beyond design and into the construction and setup phases of a job. Moreover, other researchers go one step farther by developing 4D CAD models, which is 3D plus time factor. 4D CAD models are being used to visualize the transformation of space over time, by combining 3D CAD models with a schedule for the facility activities.

In this present research, the focus will be on 3D CAD models. Regrettably, 3D CAD modeling is not used in the conceiving and conceptual phase of a project life. Xu (2000); Marir et al. (1998) consider that although 3D CAD systems are extremely powerful, they are not being utilized thoroughly in the Architecture, Engineering, and Construction (AEC) industries. Specialists in the AEC industry have used today's CAD systems as simply automated drafting tools, which are limited to their own narrow areas of specification rather than extended to creating product objects that could later be utilized by other applications. Moreover, Al-Hussein (1999) states that although graphics using CAD systems and 3D are capable of representing the crane and the on-site physical objects and to facilitate an efficient planning environment, they are not amongst the premiere tools used in crane selection and the crane operation domain. Zahnan (2001) supposes that the use of 3D CAD models empower the accuracy of designs and minimize the field changes caused by design errors and emission. Similarly, Vaugn (1996) considers that 3D models allow one not only to visualize the project from any point in space, but also to eliminate errors actively at the point of design. Kim et al. (2000) believe that 3D CAD applications are used for effectively representing the graphic information in the design phase. The basic quantity information obtained from 3D object models is directly used as the parameters of functions established for creating the specific quantity information tables in the cost estimating phase. Alternatively, Bouvrie (2000) thinks that current 3D and intelligent 2D CAD systems do not provide an effective method of controlling the production of a design. Although data can be extracted from them, it is a laborious process that is also hard to manage. Kunigahalli (1997) believes a 3D modeling scheme that facilitates efficient computer-based storage and manipulation of geometric and topological information is required in order to develop powerful CAD systems for a rapid design process and for computer-aided process-planning systems for fast and cost-effective construction. Therefore, 3D CAD modeling is an important and necessary step in all phases of the project life. It helps in eliminating design errors and emissions before starting the physical implementation. Accordingly, it reduces costs. Further, retrieving the required parameters automatically from the 3D CAD model reduces time consumption in generating parametric estimates.

3.4 Computer Integrated Construction (CIC)

Due to its nature, the construction industry is fragmented because of the lack of shared information between concerned parties. This fragmentation impacts on consumed time and costs. Lipman and Reed (2000) believe that effective project delivery depends on making current and correct information available to all project participants wherever they are and whenever they need it. Hemiö and Salonen (2000) believe that data transfer in the future will be based more on sharing than on sending. Hence, all project participants should be capable of sharing data frequently by using available technologies. Generally, to integrate means to combine individual elements and optimize the performance of the whole facility, and not just one of its separate organizational components (Sanvido and Medeiros, 1990). In construction, Computer-Integrated Construction (CIC) is emerging as a promising technology to enhance the productivity and efficiency of the Architect/Engineer/Construction (A/E/C) industry in the 21st century (Kunigahalli, 1997). Jung and Gibson (1999) state that the concept of CIC is mainly derived from that of Computer Integrated Manufacturing (CIM), which refers to the integrated information processing requirement for the technical and operational tasks of an industrial enterprise that are the production planning and control system. Researchers have not given a unique definition for CIC, yet Teicholz and Fischer (1994) define CIC as a business process that links the project participants of a facility project into a collaborative team through all phases of a project. On the other hand, Sanvido and Medeiros (1990) define CIC as the better use of electronic computers to integrate the management, planning, design, construction, and operation of constructed facilities. Furthermore, Miyatake and Kangari (1993) deem CIC a strategy for linking existing and emerging technologies and people in order to optimize marketing, sales, accounting, planning, management, engineering, design, procurement and contracting, construction, operation and maintenance, and support functions. Moreover, Jung and Gibson (1999) believe CIC is the integration of corporate strategy, management, computer systems, and IT throughout the project's entire life cycle and across different business functions while Zahnan (2001) thinks CIC strives to bridge the gaps of information by integrating the tools and processes within the Architecture, Engineering and Construction industries. Kim et al. (2000) consider that CIC is a good project management and communication tool by which all the information produced during the entire project life cycle can be efficiently shared, managed and controlled among various business functions within an organization. Björk (1994) states that CIC describes a future target stage of the use of information technology in construction. The key factor in CIC is the integration of the different computing applications used in the life cycle of a building (for instance CAD, engineering analysis, production planning, facilities management). Such integration will take place via automated digital data transfer between applications.

Deriving from the listed definitions, this present research defines CIC as an emergent technique that combines the phases process of a construction project's life in a unified manner that employs advanced computer applications to eliminate the fractured interaction between stakeholders, to lessen cost and time and to enrich efficiency and accuracy.

3.4.1 Goals of CIC

Teicholz and Fisher (1994) have summarized the goals of CIC as follow:

- *Rapid Production of High-Quality Design:* reducing the time required for design and construction without sacrificing facility quality and increasing project cost (this is a primary goal of CIC).
- *Fast and Cost Effective Construction of Facility:* the use of 3D models permits more accurate designs that avoid the need for field changes caused by design oversights and errors. Design modifications can be communicated quickly among the client, contractors, and engineers.
- *Effective Facility Management:* a completed facility requires systems that can be used to manage it. The largest gains of CIC will be in the ability to use, for facility management, the data and models developed during these phases.

Additionally, Miyatake and Kangari (1994) think CIC results from:

- An integrated information flow.
- The widespread application of computers.
- High levels of automation.

However, the ultimate goal in any company should be to integrate the entire operation. CIC is a concept of a totally optimized, and integrated company, whereas Kunigahalli (1997) deems that the integration of design and construction is an essential requirement to achieve the primary goals of CIC.

In this present research, integrating Computer-Aided Design (CAD), especially 3D CAD drawings with relational cost databases to automate the preparation of reliable and accurate conceptual cost estimates, is considered the primary goal of CIC.

3.5 Summary

This chapter addresses the importance of Management Information Systems since the availability, types, and sources of historical data have a major impact on the preparation and accuracy of cost estimates and anticipated LCC. Therefore, storing the required data in relational databases would speed the retrieving, querying and modifying practice whenever needed. 3D CAD drawing provides the visualization of the building project before its physical implementation is carried out. Retrieving and accumulating the required parameters from the 3D drawing have the potential of accelerating the preparation of more accurate and reliable parametric cost estimates. Furthermore, this chapter has given an extensive overview of the importance of applying Computer Integrated Construction to the industry. The literature review illustrates that CIC is capable of improving efficiency, of reducing time and cost, and of minimizing, if not entirely eliminating, errors and omissions during different phases of construction. However, it was found that those advantages have left behind the conceiving and developing phases of a project life despite their importance to management and decision makers. Consequently, there is the need for an integrated system to be used at these phases.

Hence, the aim of this present research is to design and implement a system that integrates construction cost estimates, forecasting, life cycle costing, 3D CAD drawing, Management Information System, and Virtual Reality Environment to be used at the feasibility phase of a project.

CHAPTER FOUR

SYSTEM DEVELOPMENT METHODOLOGY

4.1 Introduction

This chapter discusses the methodology of developing an Integrated Conceptual Cost Estimating and LCC System for Building Projects. The system's requirements are established according to the comprehensive literature review presented in preceding chapters along with the characteristics to be considered in a practical system. The methodology is divided into five main phases.

- Phase one consists of designing the system's relational databases for parametric and preliminary cost estimates, Life Cycle Costing and Sensitivity Analysis, and 3D-CAD Drawings.
- Phase two comprises the design of AutoCAD's internal modules, customize, and create new drop down menus.
- Phase three involves the design of a global module that acts as a platform to manage the project cost data retrieval and executes all required adjustments and calculations for parametric estimates.
- Phase four covers the design of an LCC module to forecast the running costs of the facility during occupation. This includes the application of the sensitivity analysis method to predefined parameters.
- Phase five incorporates the applications of linear regression method to the generation of sets of equations. These equations are based on the

building's exterior wall and framing type and on the size or budget entry. Furthermore, in the system, there is a decision support system (DSS), which automates the selection of project type and its associated 3D-CAD drawing from cost and 3D-CAD drawing databases based on the budget entry.

4.2 System Requirements

System requirements are based on the literature review described in previous chapters. The project cost estimate involves data gathered from different sources; these include drawings, specifications, general conditions, and bill of quantity. A system integrating these sources in order to prepare reliable conceptual cost estimates would be useful. Following are the steps in developing such an integrated system:

1 Designing and implementing eight different databases for parametric and preliminary cost estimates in imperial and metric units. This is done In addition to creating two other databases for LCC & S.A.

2 Collecting historical cost data from previously executed projects and storing them in these databases.

3 Employing Masterformat divisions and Assembly elements for parametric and preliminary estimates as WBS in units' both imperial and metric.

4 Linking AutoCAD to these cost databases to automate the preparation of parametric estimates based on the new parameters.

5 Customizing AutoCAD main menu to ease the process of reading and exporting associated 3D drawing's parameters to the external database. Also, designing and implementing a 3D-CAD drawing database to be used by the decision support system in selecting the best project.

6. Adjusting previous projects' costs according to city index, inflation, size, perimeter, height, and external walls and structure frame types.
7. Providing built-in cost based on R. S. Means Cost Data for both WBS's, with the possibility of using one's own cost data for preliminary estimates.
8. Forecasting the future costs of running the facility as well the anticipated income within a selected life based on BOMA data and applying sensitivity analysis method to identify sensitive parameters.
9. Using linear regression equations to forecast the costs of proposed projects based on their size or budget entry.
10. Automating the project selection process and a 3D-CAD drawing originated on budget entry through a decision support system designed for this purpose.
11. Transferring the adjusted 3D CAD drawing to a Virtual Reality format for visualization and animation through a Virtual Reality Browser.
12. Generating various formats of predefined professional output reports.

Supplementary to these steps, the system is to have the following characteristics:

- Information intensive; it incorporates different databases to store and use available data in an attempt to improve the practicality of preparing parametric and preliminary estimates and life cycle costing.
- Efficient; it automates parameters' readings from 3D CAD drawings and their normalization and adjustment methods.
- Flexible; it allows cost data addition and modification to add up the historical data in a user-friendly mode.
- Practical; it includes procedures for carrying out fast calculations by applying available tools (expressions, equations and Structured Query Language SQL).

- Virtual; it provides 3D animation of the proposed project using a Virtual Reality Browser.
- Automatic; it supplies users with quick support in selecting the best project that suits the keyed-in budget and the closest 3D-CAD drawing that has a contiguous size similar to the forecasted one.

4.3 System Components and Architecture

The system consists of components designed in a modular format, incorporating five modules: AutoCAD module, conceptual cost estimates module, global visual basic module, Life Cycle Costing & Sensitivity Analysis module, and Decision Support System & Forecasting module. Figure 4.1 shows the system's components. AutoCAD module is linked to an external database, which in turn is linked to the four parametric cost estimate and the LCC databases. All these databases are managed by a database management system. The functions performed within each of the system components and their local developments are described in coming paragraphs.

Based on the user's input, the system guides the user throughout the estimating process. The global visual basic module manages the process of accessing required data based on the estimate's type, besides executing all required adjustments and calculations. The system incorporates the imperial and metric parametric databases using R. S. Means published cost data in both Masterformat and Assembly work breakdown structure, assisting the user in normalizing the costs of a previous projects.

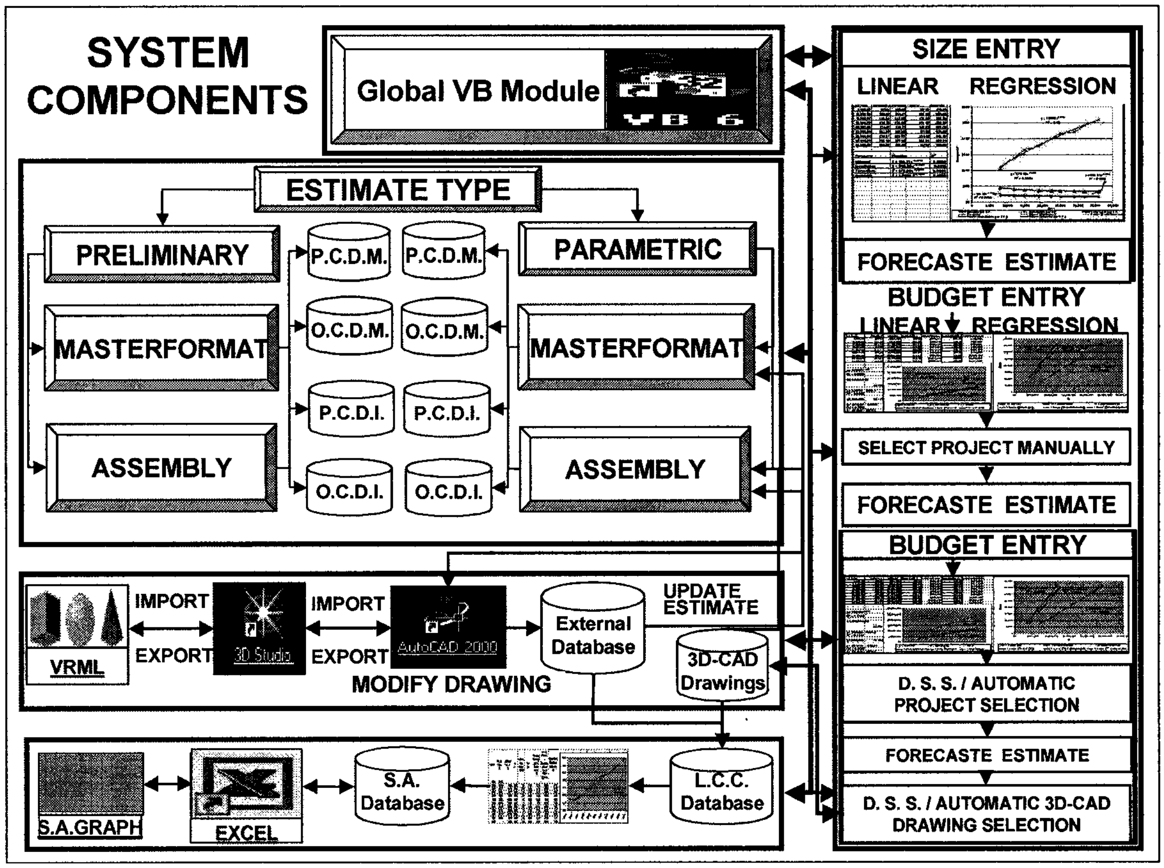


Figure 4.1 System Components.

This normalization is done for city cost index, inflation, size, perimeter, height, external walls, and structure frame types. The user will be able to quickly prepare a parametric estimate for any similar project listed in the provided database in both metric and imperial units. The preliminary estimate module that integrates the preliminary databases based on Masterformat and Assembly WBS supplies the user with the option of either using R. S. Means published cost data or inputting his or her own cost data to build up the databases. On the other hand, the AutoCAD modules read the 3D CAD drawing parameters that are the following: floor area, floor-to-floor height, and building perimeter. These parameters are written to an external database, which is linked to the parametric cost databases. The Life Cycle Cost module, which is linked to the Life Cycle

Costing and Parametric cost databases, executes, and forecasts the income, maintenance, and operating costs based on BOMA data.

In preparing an estimate, the system follows these steps:

1. Selects WBS (Work Breakdown Structure), either Masterformat or Assembly.
2. Selects Data Source, either R. S. Means published or one's own cost data.
3. Uses imperial or metric units.
4. Generates 3D CAD Drawing, modifies, and exports to rendering software then to Virtual Reality Environment.
5. Makes Cost Adjustment, using R. S. Mean's city cost index, inflation rate, size modifier, height, perimeter, and external enclosure adjustments.
6. Calculates the LCC, based on Income and Expenses adjustment factors, inflation and interest rate, other income and salvage value, life period, rent and retail area, and rental rate.
7. Makes estimate forecasting based on area or budget entry, exterior and frame type.

Figure 4.2 shows the system architecture. The process starts by selecting the estimate type. Units' type, Work Breakdown Structure (WBS), city and building type govern the parametric estimate selection. WBS, project information, cost data, unit, city, and item's quantity governs the preliminary estimate choice. On the other hand, land area, cost per square foot, rent and retail area, other income and salvage value, rental rate per square foot, life period, inflation and interest rate manage the LCC choice. Proposed area, budget, wall and frame type, indirect costs and inflation control the forecasting selection. The data analysis depends on the estimate type selected by the user as well as on the output reports that can be either tabulated or graphical.

4.4 System Databases (Phase 1)

Loucopoulos (1992) states that a consistent information system depends on the integration between databases, programming languages, and software engineering; its lifecycle incorporates the interrelated technologies of conceptual modeling and database design. Based on this statement, designing and implementing the system's relational databases are divided into two steps: the Conceptual Modeling and Implementation Data Model. Figure 4.3 shows the system's database development process.

4.4.1 Conceptual Modeling

The Conceptual Modeling step includes problem investigation, user requirements, model's components, and architecture. The database necessities are identified afterwards, the conceptual design is carried out, and the conceptual schema (Entities-Relationship Diagram) is derived. As described in chapters two and three, the problem investigation and user requirements are set and identified. The model's components and architecture have already been identified in previous paragraphs. The conceptual design can be established by identifying the components of the conceptual schemas. The conceptual schema concentrates on describing the database entities, their attributes, and relationships. The graphical presentation of the conceptual schema is developed

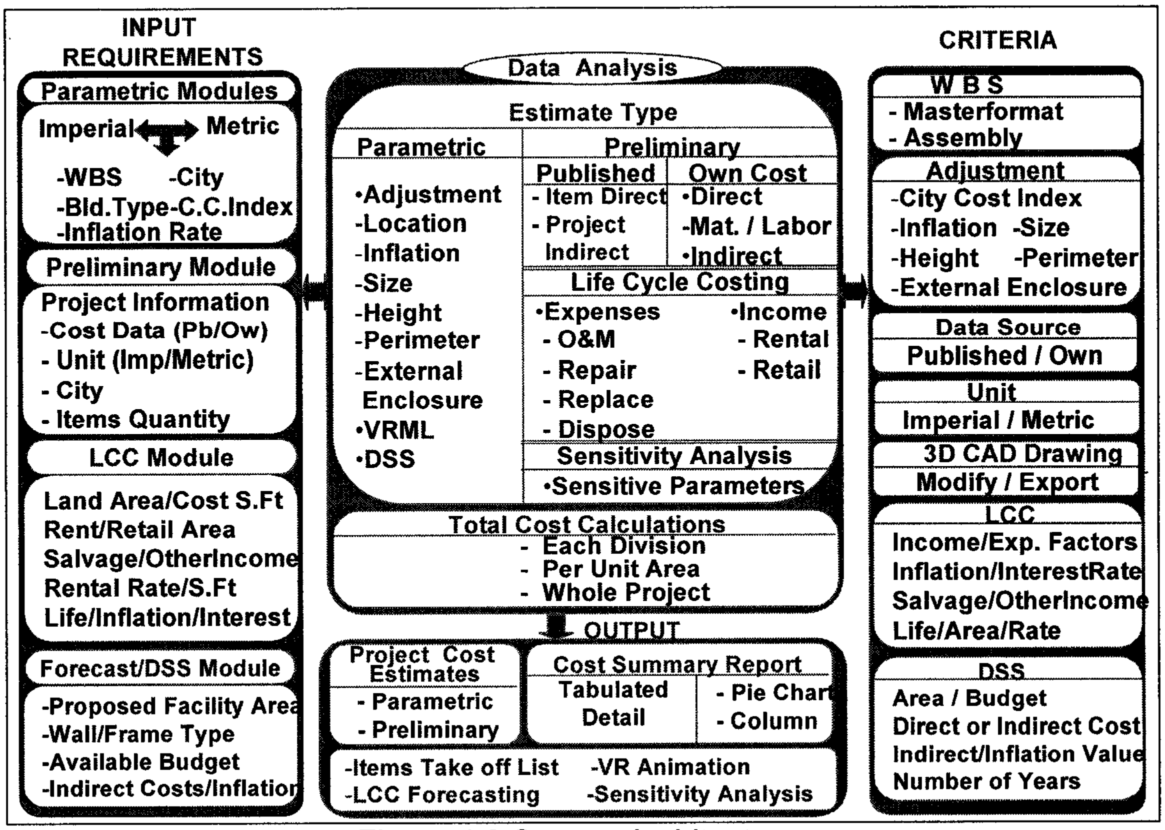


Figure 4.2 System Architecture.

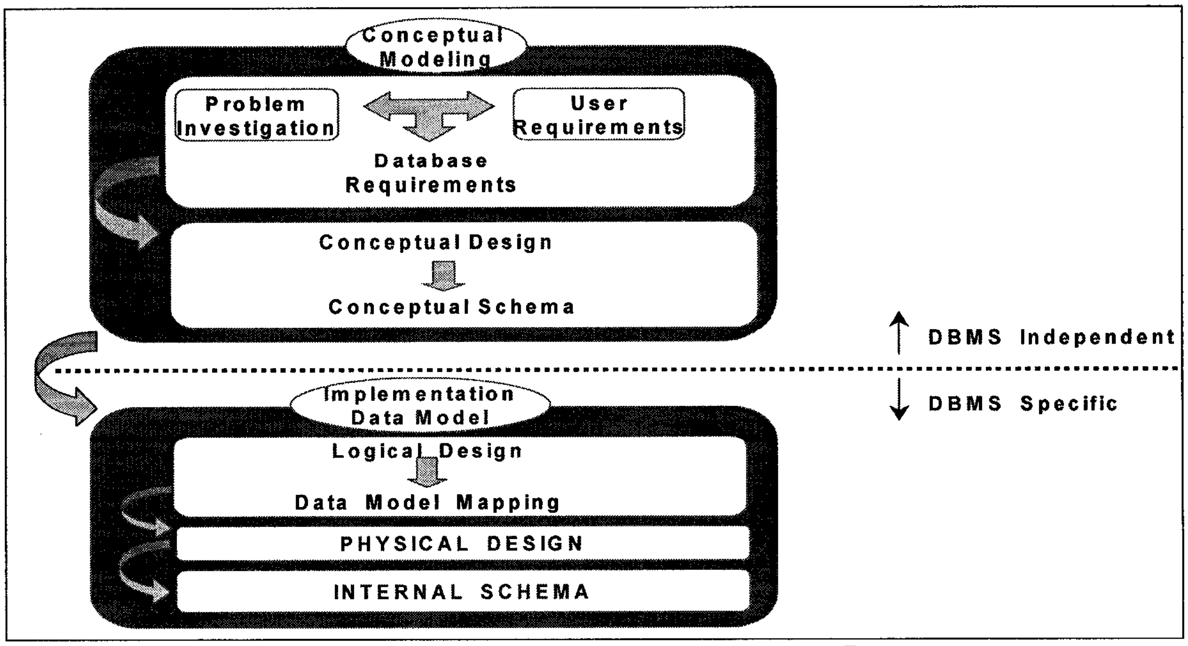


Figure 4.3 System's Database Development Process

by using an approach known as Entity-Relationship Diagram (ERD). In the presentation, entities are identified with rectangular shapes; attributes that are the values of those entities have oval shapes, and the business relationships between entities have diamond shapes.

- **Entities** are the primary data objects about which information is to be collected. They represent the real world concepts that are stored in the database. The cost estimate database comprises many entities. (e.g. Project, Division, Element, Cost Estimate, Cost Source).
- **Relationships** represent the associations among one or more entities. The different type of connectivity between entities are the following: one-to-one (1:1), one-to-many (1:M), and many-to-many (M:N). In this research, all three types are used.
- **Attributes** are the values and characteristics of entities. They can be single, composite or multi-valued (Quantity, Unit Cost, Item Description, Item Number are examples of the attributes used in the databases).

Figures 4.4 shows part of the conceptual schema designed for the preliminary cost estimate database in both metric and imperial units and for the work breakdown structure. It consists of six main entities: Project, Division, City, Cost Estimate, Element, and Cost Source. Each of these entities has one or more attributes, while one of these is a composite attributes which itself has many attributes (e.g. item). The relationships between most of these entities' are many-to-many and one-to-many. Figure 4.5 illustrates a portion of the conceptual schema designed for the parametric cost estimate database in both units and

Assembly work breakdown structure. In this case, the Enhanced Entity Relationship approach (EER) is used since one of the main entities has complete specialization. This entity comprises two main entities that are Project and Division but the Project entity has three sub-classes, which are Commercial, Industrial and Institutional. Each of these sub-classes has a weak-entity that is Exterior Wall Type, while the Division has one weak entity, which is element. Each entity type has many attributes either single or multi-valued. The relationship between these entities is mainly (1:M) and one (M:N).

A similar process has been followed in designing the AutoCAD external database, 3D-CAD drawing database, and LCC and S.A. databases. Rent Income Value; Retail Income Value; Expenses Income Value; and City Income Expenses Factors are examples of the entities used in the LCC database. Additionally, the range of the deviation entity is an example of the S.A.

Once the required conceptual schema of each database is drawn, the Conceptual Modeling step is accomplished and subsequently the Implementation Data Model can be carried out. Detailed explanations of this implementation are provided in chapter Five “Development Process”.

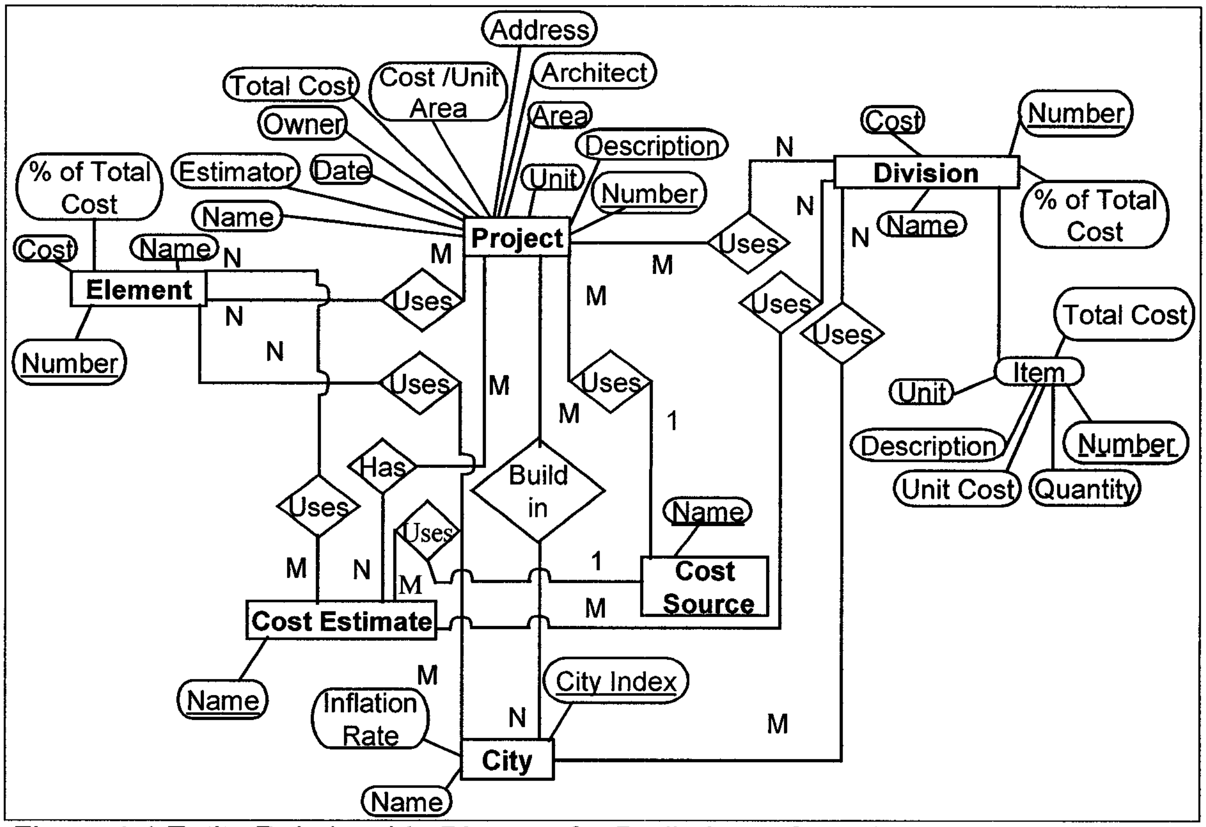


Figure 4.4 Entity Relationship Diagram for Preliminary Cost Estimate Databases

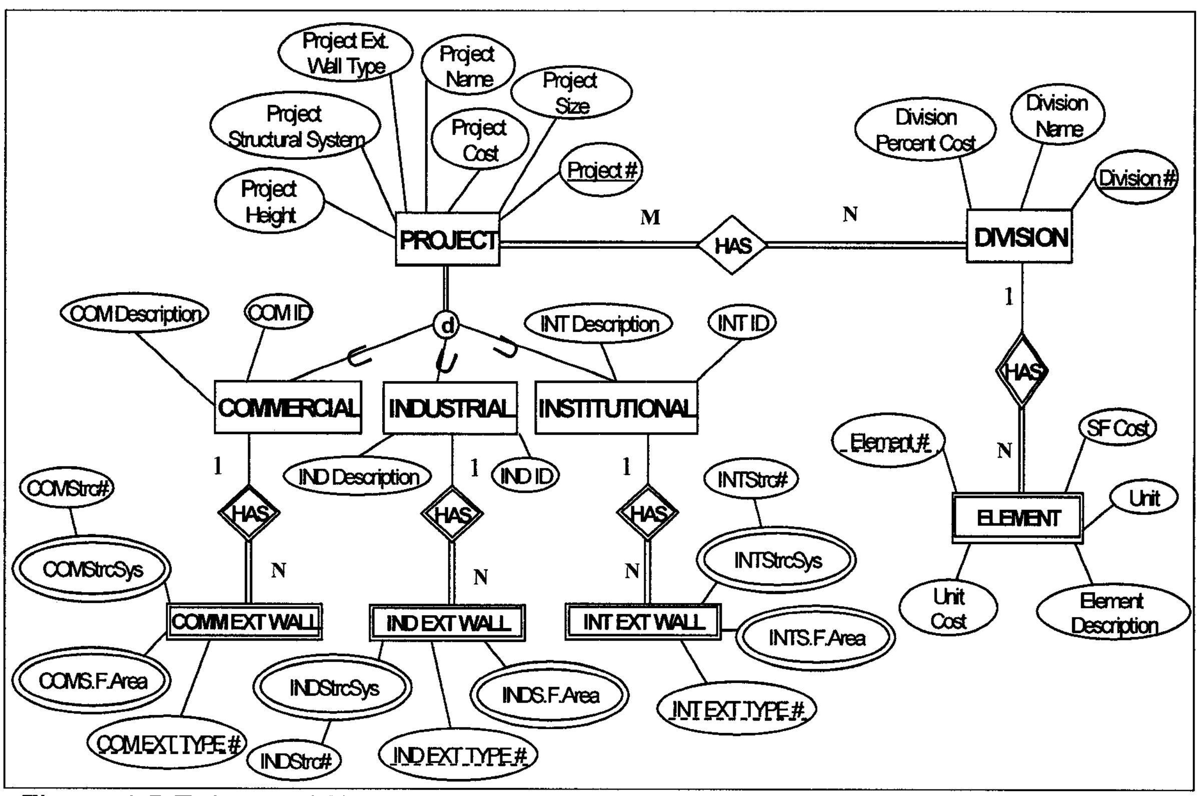


Figure 4.5 Enhanced Entity Relationship Diagram for Parametric Cost Estimate Databases

4.4.2 Preliminary Estimate Module

Preliminary estimates are used at the conceptual design phase where normally 40% of the design drawings and specifications are available. At this point, direct costs of material, labor, and equipment can be estimated, as well as the indirect costs including profit, contingency, project overhead, sales tax, and professional fees. These types of cost constitute the core of the module that integrates the preliminary cost estimate database. To prepare cost estimates, the system uses expressions and equations to calculate the project's direct and indirect costs depending on the selected type of cost data. To start, the user is required to input general information about the project. The user also needs to select one of the eight major Canadian cities where the project is to be built. The system will guide the user in preparing the take off list by providing the divisions of the breakdown structure of the chosen work. After entering the quantity of each of the selected line items from the list, the module calculates its direct cost using the following expression:

Item direct cost = (item quantity) x (item unit cost) [4.1]

The module is designed to be user friendly by allowing deletion, modification, and updating for the built-in cost data. The total direct cost of the project can be provided according to the requirements of the user.

Based on the input values of the Sales Tax (ST), Profit (PR), Overhead (OH), Architecture Fee (AF), and Contingency (CT), the module calculates the indirect costs by using equations [4.2] to [4.6].

PR cost = (PR value entered) x (project direct cost)/100 [4.2]

OH cost = (OH value entered) x (project direct cost)/100 [4.3]

AF cost = (AF entered) x (project direct cost)/100 [4.4]

CT cost = (CT value entered) x (project direct cost)/100 [4.5]

ST cost = (ST value entered) x {(project direct cost) + (PR cost) + (OH cost) + (AF cost) + (CT cost)} / 100 [4.6]

Afterwards, the module calculates the total project costs and the cost per unit area using equations [4.7] and [4.8] respectively.

Total project cost = Σ(project direct cost + ST cost + PR cost + OH cost + AF cost + CT cost) [4.7]

Cost / Unit Area = {(Total project cost) – (ST cost)} / (Total Area) [4.8]

To simplify the implementation and development procedures of the preliminary estimate module a data flow diagram has been created as Figure 4.6 outlines.

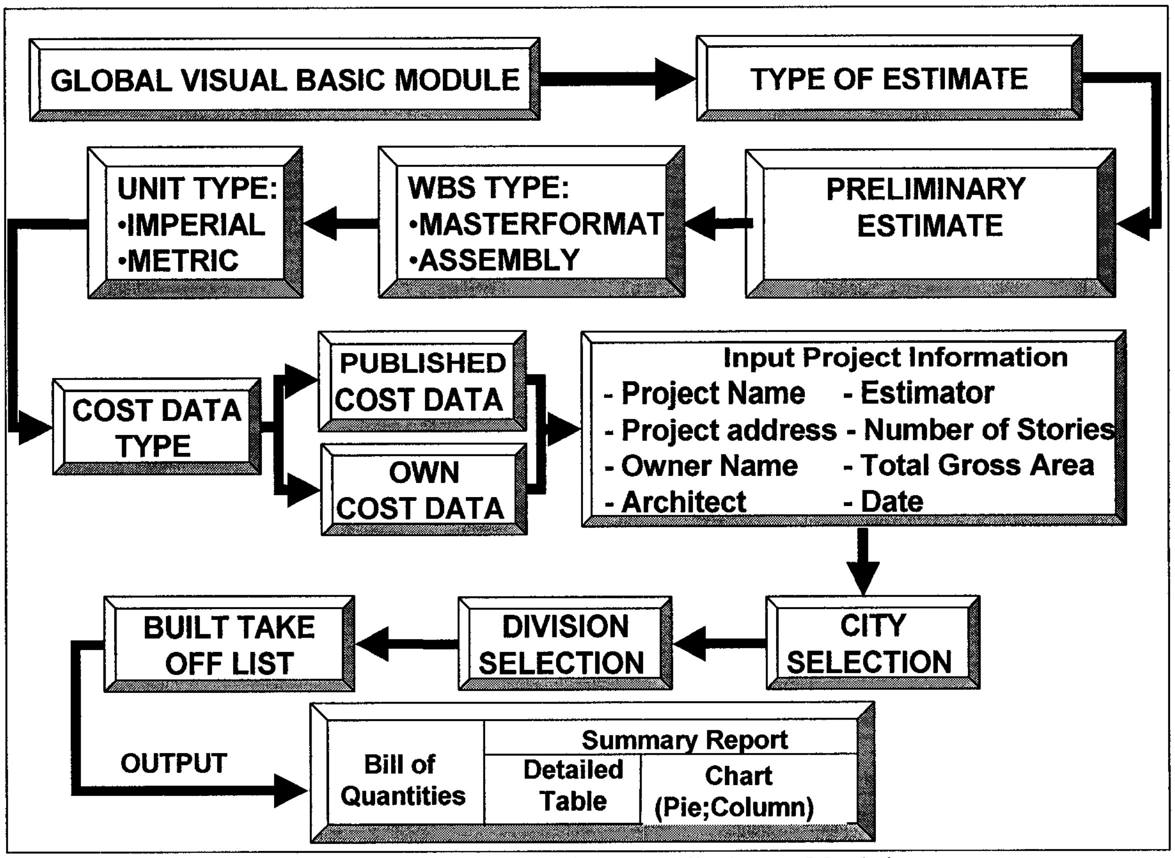


Figure 4.6 Data Flow of the Preliminary Module.

4.5 AutoCAD Module Design (Phase 2)

This phase consists of customizing AutoCAD to fit the modularity requirements of the system. This customization is achieved through employing AutoCAD built-in Visual Basic for Application and Auto Lisp. The first step is to design and implement a Visual Basic module capable of automatically reading the compulsory parameters from the 3D CAD drawing and then to write them to the external database as illustrated in Figure 4.7. However, the module should be able to execute the following:

- Allow the user to extend or shrink any selected part of the 3D drawing in any direction by scrolling the mouse.

- Allow the user to add or delete floors.
- Read and write, to an external database, the new area and height of each floor, and the new perimeter after modifying the 3D CAD drawing.
- Facilitate the process of manually exporting the modified 3D drawing to rendering software (3D Studio Max 3.0) so that it can be rendered and then to Virtual Reality Environment.
- Customize AutoCAD drop-down menus so users can easily choose to execute any of the previous procedures by a single mouse click.

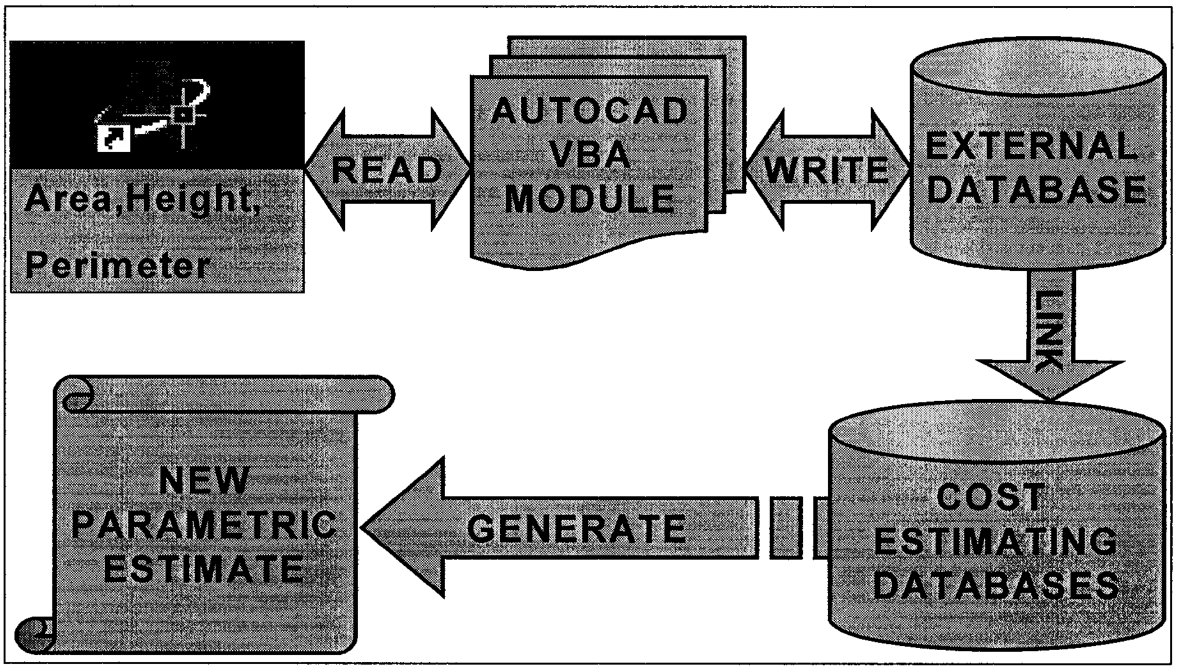


Figure 4.7 Reading and Writing Parameters to the Database

Setting these requirements would ease the development process of the module. In order to allow the user to expand or reduce the selected floor(s) size, many trials have been done to find the best way to achieve this goal. It was found that a specific type of line has to be used in the 3D CAD drawing, which is the LWPolyline. It is easy to stretch or shrink this type of line depending on the user needs in 2D and 3D mode.

To start, an AutoCAD visual basic project has to be created. This project includes all the required components of the module. After creating this project, Auto Lisp files are modified so that the preceding project is automatically loaded every time AutoCAD opens. This step will be explained later in chapter Five. To automate the writing process to the external database, a connection has to be made between AutoCAD and that database. Microsoft OLE DB Provider for ODBC Drivers is applied where MS Access Database is the Machine Data Source for the connection string.

Area and height (Thickness) are properties in the VBA Object Model for the LWPolyline type used in the 3D drawing. Therefore there is no need to any equation to calculate them in the module. However, the perimeter (length) property is not included so it should be determined by using appropriate equations based on the coordinates retrieved from AutoCAD.

4.5.1 Exporting 3D CAD Drawing to VRE

Once the associated 3D CAD drawing is modified, users need to animate it in virtual reality to visualize its sides from all points in space before the physical construction takes place. Based on the literature review the best way to animate the building in 3D mode is through the use of VRE by applying VRB. Although it is possible to write hundreds of VRML coding lines to create and animate a building in a 3D manner, this is not the aim of this research. Instead, a CAD model is translated into VR either directly or through the intermediate stage of a rendering package; this research uses 3D Studio as a rendering package to transmute the drawing to VRE. Figure 4.8 exemplifies the transforming methods.

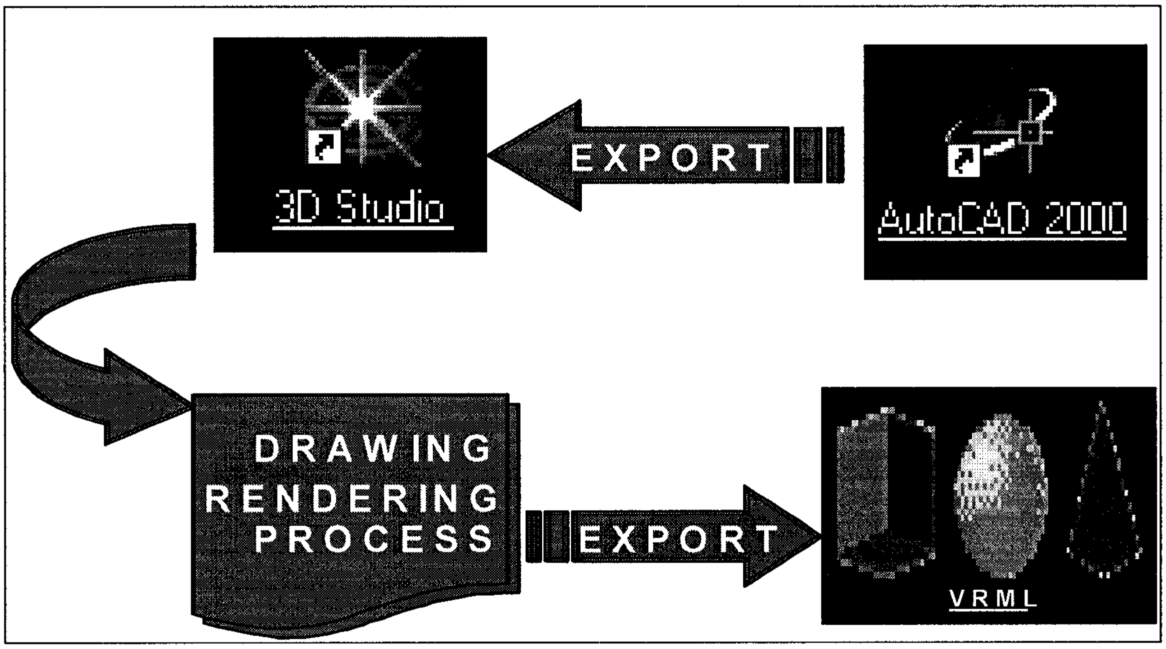


Figure 4.8 Transferring from CAD to VRE

From AutoCAD the user exports the modified 3D drawing, which has a (.dwg) format to 3D Studio (.3ds format). Then in 3D Studio, the user imports the new (.3ds) drawing for rendering and adds any required environment to it. Once satisfied, the user exports it to (.wrl format) which is the virtual reality format for visualization and animation.

4.6 Global Visual Basic Module (Phase 3)

This module is considered the gateway that incorporates the parametric estimate module and manages the access to other modules and data retrieval. To simplify the development of this module a workflow diagram is structured to show the procedures followed in contacting the required modules and data. Figure 4.9 illustrates the system's workflow structure diagram.

Numbers of drop-down menus were developed to assist in the selection of the estimate type and accordingly choose the work breakdown structure, unit, cost, and data type. For the parametric cost estimate, project's type, area, exterior wall and frame type, administer the retrieval of the associated data.

The module retrieves parameters from the modified drawing from the external database and automatically adjusts them using procedures and equations provided in the succeeding paragraphs. Adjustments for exterior wall enclosure and frame structure type are inherent in the module and database in a way that these adjustments are automatically made depending on the user selection as shown in Figure 4.9.

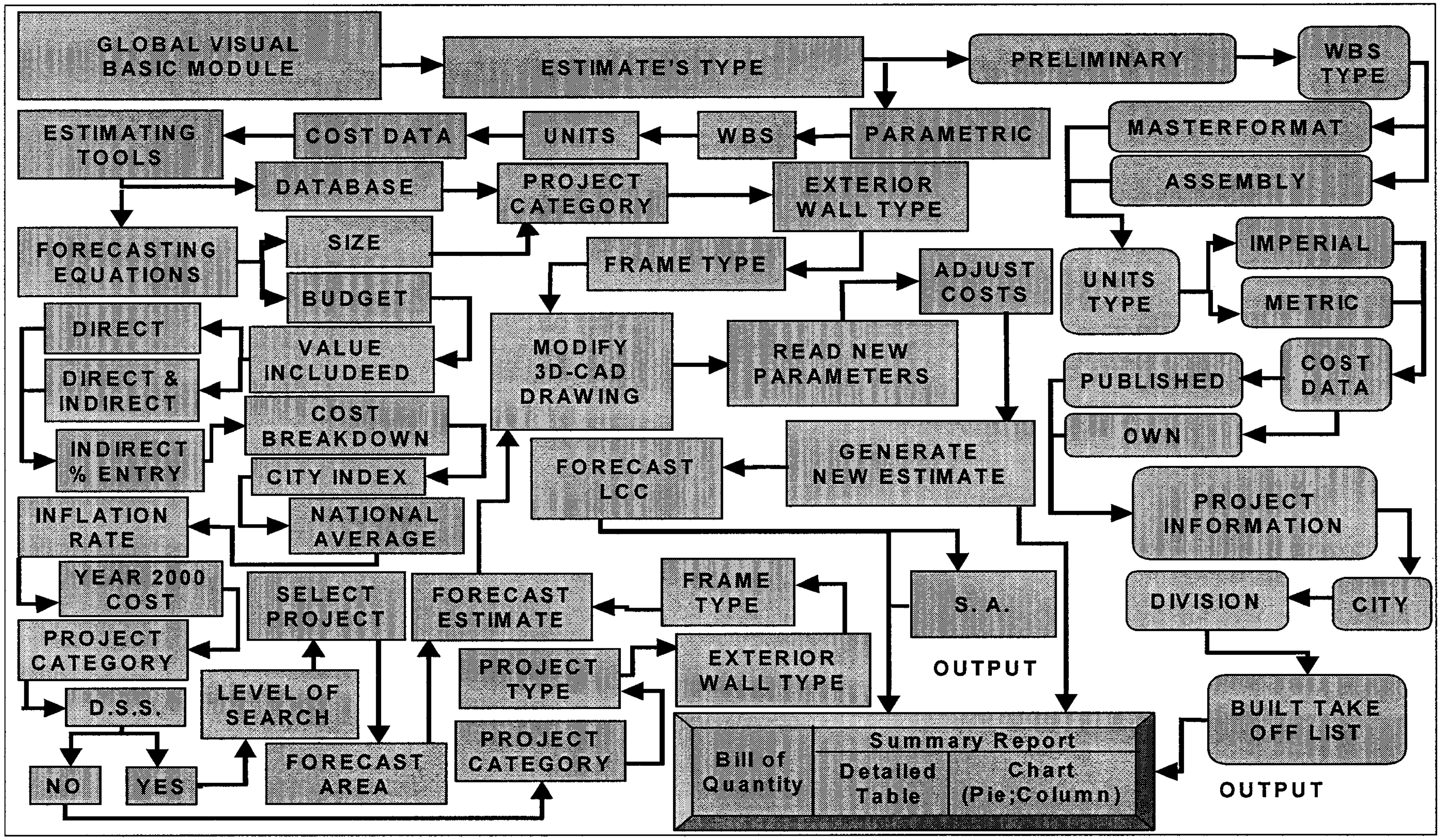


Figure 4.9 System's Workflow Structure.

4.6.1 Adjustment for Size

Peurifoy and Oberlander (2002) state the following: the cost of a previous project used in forecasting the cost of a future project has to be adjusted for the difference in size between the two projects. Therefore, the new area derived from the modified drawing has to be adjusted for size difference. This adjustment is made using the project size modifier supplied by R. S. Means, as shown in Figure 4.10.

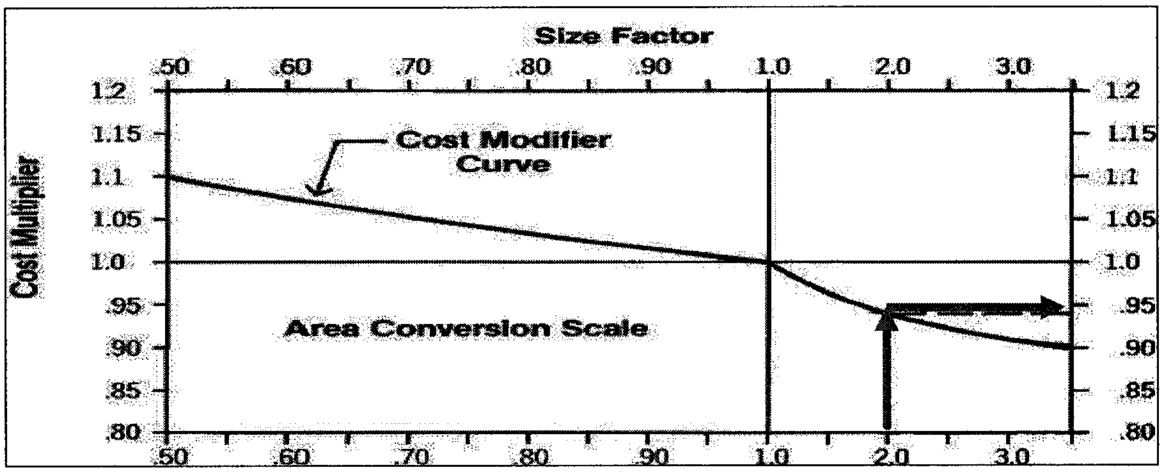


Figure 4.10 Project Size Modifier *(After R. S. Means, 2000)*

The adjustment for size using the graph starts by choosing a similar project to the proposed one from the list provided by R. S. Means as shown in Figure 4.11.

For each project, the three following values have been supplied: Median Cost/S.F., Typical Size Gross, and Typical Range Gross.

Assume that the proposed building is a Mid-Rise Apartment Building having an area of 100,000 S.F. and assume that the typical size of the similar Project is 50,000 S.F. The ratio will be:

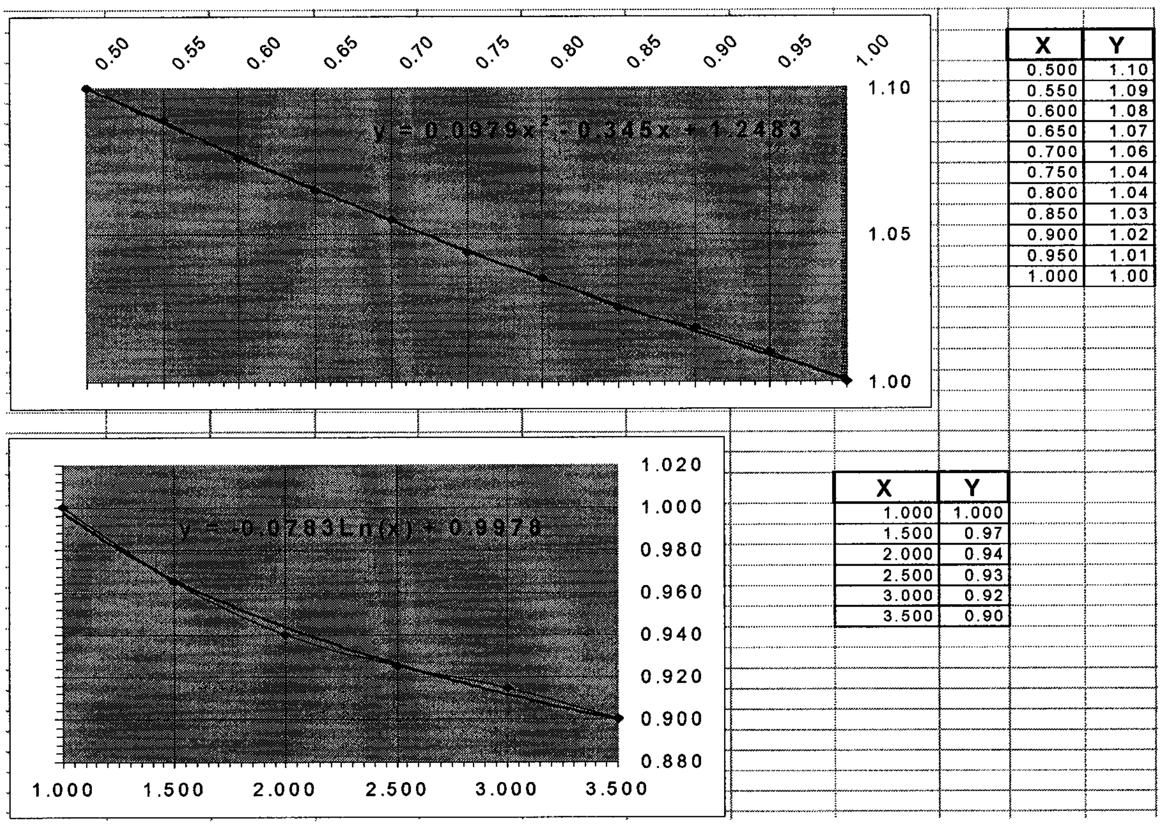
$\frac{100{,}000 S.F.}{50{,}000 S.F.} = 2.00$. In the Area Conversion scale at 2.0 we go vertically to intersect the Cost Modifier Curve at a point at which we go horizontally then we read the appropriate cost multiplier of 0.94 as shown in Figure 4.10. From the list

Square Foot Base Size							
Building Type	Median Cost per	Typical Size Gross	Typical Range Gross S.F.	Building Type	Median Cost per	Typical Size Gross S.F.	Typical Range Gross S.F.
Apartments LowRise	$54.05	21,000	9,700 - 37,200	Jails	$165.00	13,700	7,500 - 28,000
Apartments Mid Rise	68.25	50,000	32,000 - 100,000	Libraries	97.30	12,000	7,000 - 31,000
Apartments High Rise	78.30	310,000	100,000 - 650,000	Medical Clinics	93.15	7,200	4,200 - 15,700
Auditoriums	90.35	25,000	7,600 - 9,000	Medical Offices	87.50	6,000	4,000 - 15,000
Auto Sales	55.90	20,000	10,800 - 28,600	Motels	67.00	27,000	15,800 - 51,000
Banks	121.00	4,200	2,500 - 7,500	Nursing Homes	89.95	23,000	15,000 - 37,000
Churches	81.60	9,000	5,300 - 13,200	Offices, LowRise	73.00	8,600	4,700 - 19,000
Clubs, Country	81.40	6,500	4,500 - 15,000	Offices, Mid Rise	76.65	52,000	31,300 - 83,100
Clubs, Social	79.15	10,000	6,000 - 13,500	Offices, High Rise	98.05	260,000	151,000 - 468,000
Clubs, YMCA	81.60	28,300	12,800 - 39,400	Police Stations	122.00	10,500	4,000 - 19,000
Colleges (Class)	107.00	50,000	23,500 - 98,500	Post Offices	90.40	12,400	6,800 - 30,000
Colleges (Science Lab	156.00	45,600	16,600 - 80,000	Power Plants	678.00	7,500	1,000 - 20,000
College (Student Unio	119.00	33,400	16,000 - 85,000	Religious Education	74.85	9,000	6,000 - 12,000
Community Center	85.05	9,400	5,300 - 16,700	Research	127.00	19,000	6,300 - 45,000
Cout Houses	116.00	32,400	17,800 - 106,000	Restaurants	110.00	4,400	2,800 - 6,000
Dept. Stores	50.50	90,000	44,000 - 122,000	Retail Stores	53.70	7,200	4,000 - 17,600
Dormitories, LowRise	87.20	24,500	13,400 - 40,000	Schools, Elementary	78.20	41,000	24,500 - 55,000
Dormitories, Mid Rise	113.00	55,600	36,100 - 90,000	Schools, Jr. High	79.65	92,000	52,000 - 119,000
Factories	48.95	26,400	12,900 - 50,000	Schools, Sr. High	79.65	101,000	50,500 - 175,000
Fire Stations	85.45	5,800	4,000 - 8,700	Schools, Vocational	79.35	37,000	20,500 - 82,000
Fraternity Houses	84.10	12,500	8,200 - 14,800	Sports Arenas	66.45	15,000	5,000 - 40,000
Funeral Homes	94.00	7,800	4,500 - 11,000	Supermarkets	53.85	20,000	12,000 - 30,000
Garages, Commercial	59.70	9,300	5,000 - 13,600	Swimming Pools	125.00	13,000	7,800 - 22,000
Garages, Municipal	76.40	8,300	4,500 - 12,600	Telephone Exchange	145.00	4,500	1,200 - 10,600
Garages, Parking	31.30	163,000	76,400 - 225,300	Theaters	79.70	10,500	8,800 - 17,500
Gymnasiums	78.95	19,200	11,600 - 41,000	Town Halls	87.65	10,800	4,800 - 23,400
Hospitals	149.00	55,000	27,200 - 125,000	Warehouses	36.15	25,000	8,000 - 72,000
House (Elderly)	73.90	37,000	21,000 - 66,000	Warehouse & Office	41.75	25,000	8,000 - 72,000
Housing (Public)	68.45	36,000	14,400 - 74,400				
Ice Rinks	76.00	29,000	27,200 - 33,600				

Figure 4.11 List of Previous Projects Costs($) and Area (sft) (R. S. Means 2000)

in Figure 4.11 for Mid-Rise Apartment, the Median Cost is $68.25. Therefore, the size adjusted cost becomes: 0.94 x $68.25 = $ 64.16 based on National Average Cost (after R. S. Means, 2000).

Generally, this method is carried-out manually by the user where errors are anticipated. To minimize user input and to overcome manual calculations, the module is designed to automate the measures of computing these values. Based on the graph shown in Figure 4.10, two tables have been created since the graph is a combination of two curves. The first table constitutes the curve that is limited between the Area Conversion Scale of 0.50 and 1.0. The second curve comprises the values of 1.0 to 3.5. From each table a best-fit curve has been drawn and accordingly an equation for each of these curves has been derived using MS Excel as shown in Figure 4.12 and is included in the module codes.



X	Y
0.500	1.10
0.550	1.09
0.600	1.08
0.650	1.07
0.700	1.06
0.750	1.04
0.800	1.04
0.850	1.03
0.900	1.02
0.950	1.01
1.000	1.00

X	Y
1.000	1.000
1.500	0.97
2.000	0.94
2.500	0.93
3.000	0.92
3.500	0.90

Figure 4.12 Best-Fit Graphs and their Equations

4.6.2 Adjustment for Height

R. S. Means cost data is based on a height value starting at 10 feet and depending on the building type. However, if the user decides to change the provided height when modifying the associated 3D-CAD drawing, an adjustment for height should be taken into consideration. R. S. Means supplies values that would be either added or subtracted to the cost per unit area for each one foot as illustrated in Figure 4.13.

COMMERCIAL/ INDUSTRIAL/ INSTITUTIONAL		M.020		Apartment, 4-7 Story						
Costs per square foot of floor area										
EXTERIOR WALL	S.F. Area	40000	45000	50000	55000	60000	70000	80000	90000	100000
	L.F. Perimeter	366	400	433	466	500	566	606	650	694
Face Brick with Concrete Block Back-up	Steel Frame	84.10	83.45	82.95	82.50	82.20	81.60	78.95	78.55	78.20
	R/Conc. Frame	89.05	88.40	87.80	87.85	86.95	86.85	83.30	82.55	82.45
Decorated Concrete Block	Steel Frame	79.60	79.05	78.60	78.25	77.95	77.45	75.40	75.05	74.75
	R/Conc. Frame	82.15	81.60	81.15	80.75	80.45	79.95	77.85	77.50	77.20
Precast Concrete panels	Steel Frame	81.90	81.90	80.75	80.35	80.05	79.50	76.95	76.55	76.25
	R/Conc. Frame	84.25	83.65	83.10	82.70	82.40	81.85	79.30	78.90	78.55
Perimeter Adj. Add or Delete	Per 100LF.	3.55	3.10	2.80	2.55	2.35	2.00	1.75	1.55	1.40
Story Hgt. Adj. Add or Delete	Per 1Ft	1.20	1.15	1.10	1.10	1.10	1.05	0.80	0.80	0.80

Figure 4.13 Supplied Values for Height Adjustment *(By R. S. Means, 2000)*

To illustrate this function let's consider a project from the database with the following specifications: an Apartment building with six Stories with 60,000 of square feet of floors area and a height of 10'-4". The associated drawing of the proposed building has been modified. The user has increased the height by one foot (11'-4") and the size to 80,220 S.F. In this case adjustments for size and height have to be made. The adjustment for size has been explained in the previous paragraph. Since one foot has been added to the height, then a value is added to the adjusted square feet cost according to size modification. If the adjusted square feet cost is \$76.75, then the new adjusted cost is: \$76.75 + 0.80 = \$77.55

The 0.80 is taken from Figure 4.12 based on S.F. Area of 80,000. If the user decreases the height by one foot, then the 0.80 is subtracted from the \$76.75. Generally, the user effects these adjustments manually; hence, the module automates this process and executes the required adjustment.

4.6.3 Adjustment for Perimeter

Perimeter is one of the parameters extracted from the 3D CAD drawing. Changing the floor dimension may result in changing the building perimeter and accordingly it has to be adjusted. The adjustment is made based on R. S. Means as shown in Figure 4.13 (dotted frame). In this case, the adjustment is carried-out using the perimeter retrieved by the module from the external database. Considering the same example used in previous paragraphs, its corresponding perimeter is 505 L.ft. Assume the new perimeter is 655 L.ft then the cost per unit area has to be adjusted according to this change. Using the value in figure 4.13 for each 100 L.ft beyond the 505, we have to add \$1.75. Thus, the adjusted value is the following: \$77.55 + (\$1.75 x 1.5) = \$80.2 per unit area.

On the other hand, if the perimeter is less than 505 L. ft, then the value is subtracted following the foregoing method.

4.6.4 Adjustment for Inflation

Having the costs adjusted for size, height, and perimeter, they must also be adjusted for inflation. The module immediately performs this procedure after the user inputs the inflation rate and the number of years using the following equation:

$$F = P\,(1 + i)^n \qquad [4.10]$$

Where n = number of years between known and forecasted year

F = New adjusted value due to inflation per S. Ft.

P = Adjusted value due to size, height and perimeter per S. Ft

i = Inflation rate entered by the user

The new computed value is the cost per unit area after adjustments have been made due to size, height, perimeter, and inflation.

4.6.5 Adjustment for City Location

All the cost data stored in the database are based on R. S. Means Square Foot Cost for year 2000, based on the National Cost. Thus, these cost data have to be adjusted depending on the city location. This adjustment is done through the application of the following equation:

$$C_A = C_N \left(\frac{I_A}{100} \right) \qquad [4.11]$$

Where C_A = cost in dollars for city A

C_N = national average cost in dollars

I_A = index for city A as percentage (user input)

Cost index values for the eight major Canadian cities are included in the module codes. However, the user can change them if new published values are available or if a city other than one of those included in the module is chosen. As soon as the user selects or inputs the city cost index, the module adjusts the value computed in the previous paragraph, using Equation [4.11]. Once this adjustment is made, the adjusted cost per unit area of the new project is completed and accordingly its estimate is generated. Detailed explanation of this process is provided in chapter Five.

4.7 Life Cycle Costing Module (Phase 4)

This phase consists of designing a module that automatically forecasts the operating cost of the building and its predictable yearly income based on its lifespan. This includes using sensitivity analysis on sets of predefined parameters to determine the most critical ones. Figure 4.14 illustrates the process flow of the module. The first step is to collect all the required data needed during the design

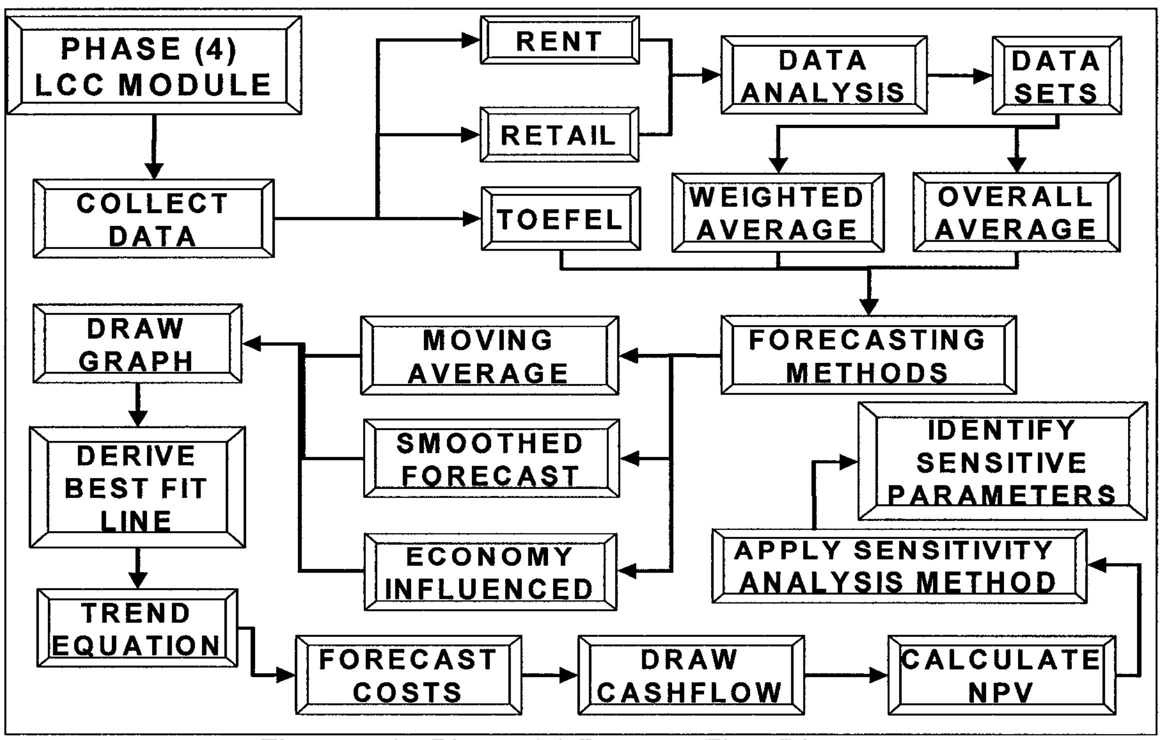


Figure 4.14 Phase (4) Process Flow Diagram

and development path of this phase. Based on the literature review, this data usually has to be internally collected from the firm's previously executed projects so that an acceptable level of confidence is anticipated. When such data is not available, published data is be used after identifying its source and level of accuracy. BOMA, (Building Owners and Managers Association), publishes data such as that which is used in this research. Data from the Consumer Price Index (CPI) published by Statistics Canada from year 1984 to 2002 is also used. Tables 4.1 to 4.4 show the collected data for Rent, Retail, TOEFEL, and CPI respectively. The components of LCC used in this present research include the following: Rent; Retail; and TOEFEL (Total Operating Expenses plus Fixed Expenses plus Leasing costs). The first two are income whereas the third is expense and consists of Cleaning; Repair & Maintenance; Utilities; Administration; Fixed Expenses; Leasing Expenses; and R.G.&S. Detailed explanations about the elements of each component used in the LCC are given in Appendix (A). Since the data used is based on BOMA reports, adjustment factors have to be applied for the LCC components. Known as impact factors (Zhang, 1999), these factors include adjustments for the following: City, Location, (i.e. Downtown/Suburban); Height of the Building (i.e. Number of Floors); Age and size (i.e. Building age and size in unit area). The factors applied on the components used in this research are the following:

- Income factors include: ICF (Income City Factor), ILF (Income Location Factor), IHF (Income Height Factor), ISF (Income Size Factor), and IAF (Income Age Factor).

Table 4.1 Office Rental ($/SF)

Year	BOMA – 5 YEARS (50 Identical Buildings)								BOMA YEARLY REPORT (200 BLDGs) (X_9)
	1989 (X_1)	1990 (X_2)	1991 (X_3)	1992 (X_4)	1993 (X_5)	1994 (X_6)	1995 (X_7)	1996 (X_8)	
1984	16.65								
1985	16.84	16.73							
1986	17.35	17.28	17.92						
1987	18.73	18.41	18.91	19.03					
1988	19.96	19.47	20.16	20.64	20.98				18.63
1989		20.98	21.57	22.92	23.40				21.09
1990			20.63	21.17	20.96				20.62
1991				21.05	22.33			23.15	21.75
1992					26.72			26.80	23.63
1993								24.15	22.57
1994								22.16	22.28
1995								20.06	21.34
1996									19.79
1997									18.80

Table 4.2 Office Retail ($/SF)

Year	BOMA – 5 YEARS (50 Identical Buildings)								BOMA YEARLY REPORT (200 BLDGs) (X_9)
	1989 (X_1)	1990 (X_2)	1991 (X_3)	1992 (X_4)	1993 (X_5)	1994 (X_6)	1995 (X_7)	1996 (X_8)	
1984	18.25								
1985	19.26	17.28							
1986	19.27	17.86	17.62						
1987	20.96	19.83	19.51	18.76					
1988	21.72	21.56	21.83	22.19	25.68				22.31
1989		22.92	23.48	23.96	26.57				24.67
1990			21.53	21.56	24.98				21.78
1991				23.89	27.34			27.97	23.70
1992					27.63			28.56	25.80
1993								26.72	23.71
1994								26.72	23.47
1995								27.12	22.63
1996									22.57
1997									15.91

Table 4.3 TOEFEL ($/SF)

YEAR	BOMA – YEARLY REPORT (200 Buildings)
1988	9.27
1989	10.09
1990	11.44
1991	11.78
1992	12.23
1993	12.67
1994	12.08
1995	12.06
1996	11.90
1997	11.69

Table 4.4 CPI (All Items/Rent) and Retail Value (Statistics Canada)

YEAR	CPI (All Items) ALL-CANADA	CPI (Rent) ALL-CANADA	Retail / year ($x1000) ALL-CANADA
1981	58.9	59.6	
1982	65.3	65.0	
1983	59.1	69.9	116,566,937
1984	72.1	73.4	127,413,320
1985	75.0	76.5	142,211,755
1986	78.1	79.6	153,785,657
1987	81.5	82.6	168,893,551
1988	84.8	85.9	181,652,071
1989	89.0	90.4	189,301,628
1990	93.3	94.1	192,558,231
1991	98.5	97.3	181,614,439
1992	100.0	100.0	185,169,503
1993	101.8	102.2	194,324,749
1994	102.0	103.9	207,840,624
1995	104.2	105.5	213,773,669
1996	105.9	106.9	220,869,830
1997	107.6	108.1	237,836,642
1998	108.6	109.2	246,674,830
1999	110.5	110.2	260,779,457
2000	113.5	111.4	277,033,166
2001	116.4	113.2	289,129,995
2002	119.0	115.4	306,365,631

- Expense factors include: ECF (Expenses City factor), ELF (Expense Location Factor), EHF (Expense Height Factor), ESF (Expense Size Factor), and EAF (Expense Age. Factor).

Table 4.5 shows IHF, IAF, EHF, and EAF for Area and Length (number of floors)

Table 4.5 Height and Age/Size Adjustment Factors for Canada *(BOMA, 1997)*

Area (SF)	Number of Floors	Age (Years)	IHF	IAF	EHF	EAF
<50K	<5	0-9	0.94	0.70	0.99	0.65
	5-9	0-9	0.98	0.70	0.98	0.65
	10-19	0-9	1.00	0.70	1.02	0.65
	20-29	0-9	1.00	0.70	1.01	0.65
	30-39	0-9	1.01	0.70	0.97	0.65
50K-99K	<5	0-9	0.94	1.50	0.99	1.17
	5-9	0-9	0.98	1.50	0.98	1.17
	10-19	0-9	1.00	1.50	1.02	1.17
	20-29	0-9	1.00	1.50	1.01	1.17
	30-39	0-9	1.01	1.50	0.97	1.17
100K-299K	<5	0-9	0.94	1.59	0.99	1.17
	5-9	0-9	0.98	1.59	0.98	1.17
	10-19	0-9	1.00	1.59	1.02	1.17
	20-29	0-9	1.00	1.59	1.01	1.17
	30-39	0-9	1.01	1.59	0.97	1.17
300K-599K	<5	0-9	0.94	2.12	0.99	1.41
	5-9	0-9	0.98	2.12	0.98	1.41
	10-19	0-9	1.00	2.12	1.02	1.41
	20-29	0-9	1.00	2.12	1.01	1.41
	30-39	0-9	1.01	2.12	0.97	1.41
>600K	<5	0-9	0.94	2.21	0.99	1.19
	5-9	0-9	0.98	2.21	0.98	1.19
	10-19	0-9	1.00	2.21	1.02	1.19
	20-29	0-9	1.00	2.21	1.01	1.19
	30-39	0-9	1.01	2.21	0.97	1.19

4.7.1 Data Analysis

The data shown in tables 4.1 and 4.2 are analyzed so that new sets of data are determined. For each of the Rental and Retail data two average-based sets (overall and weighted average) are developed and their graphs are plotted as shown in Appendix (B). Accordingly, based on Figures B.1 to B.4 in Appendix (B) the outcomes are in favor of the weighted average, which has provided relatively smooth results. Thus, the weighted average data are adopted for Rental and Retail, whereas the data for TOEFEL is considered as collected and stored in Table 4.3.

4.7.2 Forecasting Methods For Rent

In order to develop reliable equations to use in predicting the future costs of running the facility, the following two forecasting methods are evaluated: "Moving Average", and "Smoothed Forecasting" (Alkass, 2002), besides linking the forecast to the condition of the economy. A detailed explanation of this evaluation is provided in paragraph (B-2) Appendix (B).

4.7.2.1 Moving Average

The moving average forecasting is applied on the weighted average of the Rent data. First, it is applied using an incremental number of years, then a weighted average for 2 years data favoring the most recent year by 2/3, 3/4, 4/5, 5/6, and 9/10 respectively and next as a weighted average for 3 years data favoring the most recent year by 2/4, 3/5, 4/6, 5/7, 6/8, 7/9, 9/11, 11/13 and 12/14 respectively as shown in Tables B-9 through B-11 (Appendix B). The evaluation basis is the correlation between the actual data and the forecast as well as the presentation of data fluctuation.

Comparison between the three foregoing methods shows that the incremental of 2 years moving average forecast gives the best correlation with the actual data. The 2 years moving average weighted in favor of the recent year by 9/10 and gives a higher correlation of 0.78 with the original data compared to the other two methods. As such, a forecast is developed using these values for years 1998 to 2002 as illustrated in Table B-12. Accordingly, the forecasted values obtained are plotted against the actual ones and the best trend line that could be developed based on R^2 is derived as shown in Figure B.5 (Appendix B). Thus, the results show that the use of averages for this operation is not expected to provide reliable data. Therefore, this method is eliminated.

4.7.2.2 Smoothed Forecasting

In this method many runs are done to identify the one that gives the best results depending on the value of (α) starting with α = **0.05** to α = **1.0** step **0.05.** For each of these runs, a table is created and its associated graph is plotted as shown in Tables B-13 through B-31 and Figures B.6 to B.25 in Appendix B.

Hence, the higher correlation value computed from the plotted best trend line of the smoothed forecasting data is obtained for the value of (α) equal 0.20, where R^2 is 0.8302. Table 4.6 illustrates the values of (α) and the corresponding value of R^2. The relative smoothing calculations as well as the trend line plot for (α) = 0.20 are shown in Table B-16 and Figure B.9 of (Appendix B).

Table 4.6 Values of α and Corresponding R^2

α	R^2
0.05	0.7855
0.10	0.8094
0.15	0.8241
0.20	**0.8302**
0.25	0.8284
0.30	0.8201
0.35	0.8063
0.40	0.7885
0.45	0.7680
0.50	0.7459
0.55	0.7231
0.60	0.7004
0.65	0.6781
0.70	0.6568
0.75	0.6364
0.80	0.6171
0.85	0.5990
0.90	0.5818
0.95	0.5657
1.00	0.3657

4.7.2.3 Economy-Influenced Forecast

This forecast considers the influence of the economy on the future trend of the actual data, which are achieved by applying the CPI. In this analysis the following steps are conducted based on the data stored in Table 4.4.

Step-1:

The percentage change in the CPI Rent values is plotted against the percentage change in the dollars ($) value of the Rent as illustrated in Table B-32 and Figure B.26 (Appendix B). As a result, the high fluctuation in the percentage change in the rental value limits the chances of reliable forecasting. However, the correlation value of R^2 = 0.6879 between the two percentages permits further investigation.

Step-2

In this step two forecasts are developed. One is based on the actual data set using CPI-Rent Percentage to forecast the yearly value, whereas the second is based on year 1984 actual data as shown in Table B-33 and Figure B.27 (Appendix B).

Step-3

With the correlation of the forecast and the actual established data in Table B-33 (Appendix B), future data for the years 1998 to 2002 is computed.

Step-4

The best trend line is derived based on R^2 value and its plot is used to predict the future values as shown in Figure B.27 (Appendix B).

It is noticed that the developed trend line equation for 1984 actual data based forecast has better correlation factor R^2 of (0.9709) compared to the other delivered equations. Therefore, the following equation is used to forecast the expected future rent income value:

$$Y = 16.339X^{0.1565} \qquad [4.12]$$

The same procedures are applied for Retail and TOEFEL. However, the retail yearly $ value is used for the retail calculations whereas the CPI-All items is used for the TOEFEL ones.

4.7.3 Forecasting Methods For Retail

The retail data set is subject to the same procedures utilized for the rent data set. Detailed explanation about this evaluation is provided in paragraph (B-3) Appendix (B). The following equation is derived from the analysis and therefore it is used to forecast the anticipated future retail income value:

$$Y = 18.704X^{0.0949} \qquad [4.13]$$

4.7.4 Forecasting Methods For TOEFEL

Similar to the rent and retail data set, the TOEFEL data is analyzed as shown in section (B-4) Appendix (B). The following derived equation is used to forecast the future cost of maintaining and operating the facility:

$$Y = 8.8167X^{0.127} \qquad [4.14]$$

4.7.5 Sensitivity Analysis

Once the Rent, Retail and TOEFEL's anticipated values are calculated and written by the module to the database, the user is provided with the option to apply sensitivity analysis method to identify all the sensitive parameters. This is accomplished after deriving and drawing the associated LCC's cash flow. Figure 4.15 illustrates the basis of the derived cash flow. Automatically the present value

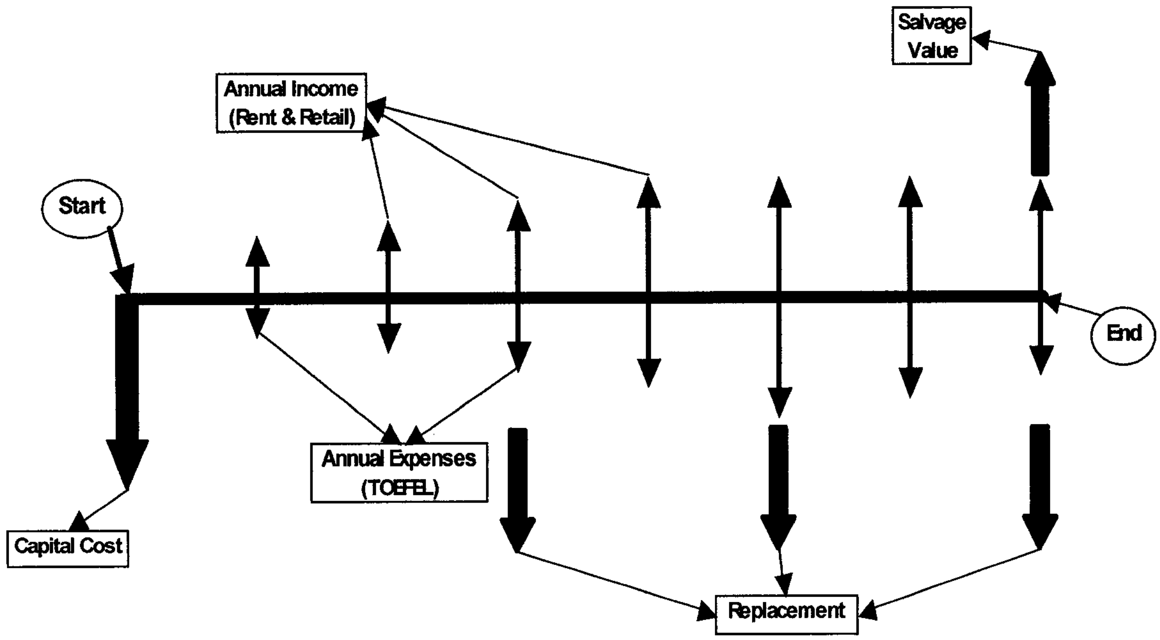


Figure 4.15 Basis of Derived Cash Flow

(PV) for each component of the derived cash flow is calculated by the module based on the interest and inflation rates entered by the user. Afterwards, a new cash flow is generated as shown in Figure 4.16.

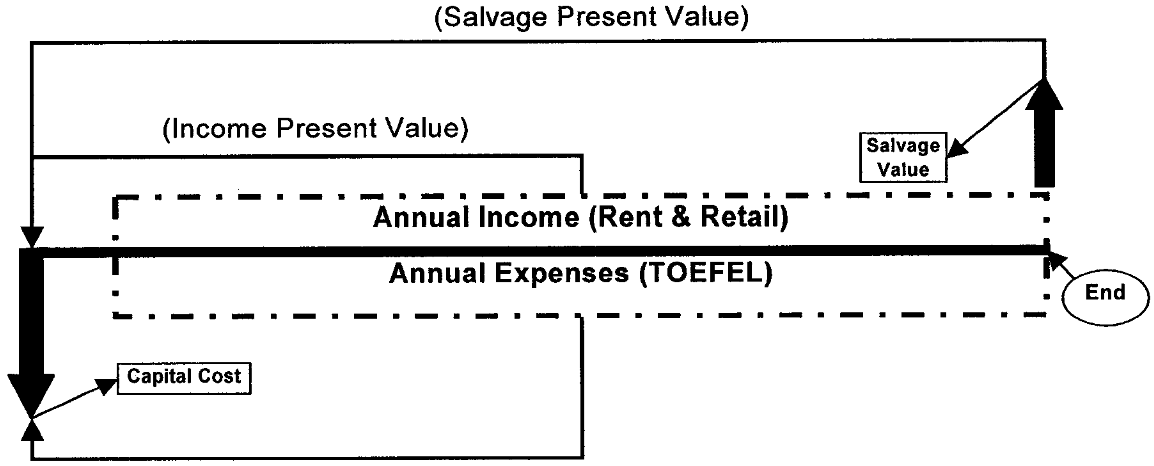


Figure 4.16 New Present Value Cash Flow

Subsequently, the module computes the Total Net Present Value (TNPV) using the following equation:

$$TNPV = \sum(\text{Income}) - \sum(\text{Expenses}) \qquad [4.15]$$

Next the Saving Investment Ratio (SIR) is automatically determined using the following equation:

$$SIR = \frac{\sum(\text{Income})}{\sum(\text{Expense})} \ldots\ldots\ldots\ldots\ldots\ldots [4.16]$$

As soon as the user inputs the range of deviation for the sensitivity analysis, the module computes the Present Worth for each component separately based on the inputted deviation, and writes these values in the database.

In order to automate the process of drawing the sensitivity analysis graph, Microsoft Excel is used due to its ability to execute this task. However, an internal module in Excel is created and its drop-down menu is customized so that the user is allowed to draw the graph by a single click from that menu. Detailed explanation for these procedures is provided in chapter five.

4.8 Forecasting and DSS Module (Phase 5)

This phase integrates a forecasting and Decision Support System (DSS) module that forecasts the costs of the proposed project once users select to use forecasting equations from the estimating techniques. This module incorporates three different sub-modules. Two of them forecast the cost based on either the size or budget entry, whereas the third encompasses a Decision Support System that automatically selects the optimum project and its associated 3D-CAD drawing that falls within the user's budget. To simplify the design and implementation procedures of this phase, a workflow diagram showing the different steps of each of the three sub-modules is designed as Figure 4.17 shows. While Figure 4.18 shows a process flow diagram for the two sub-modules.

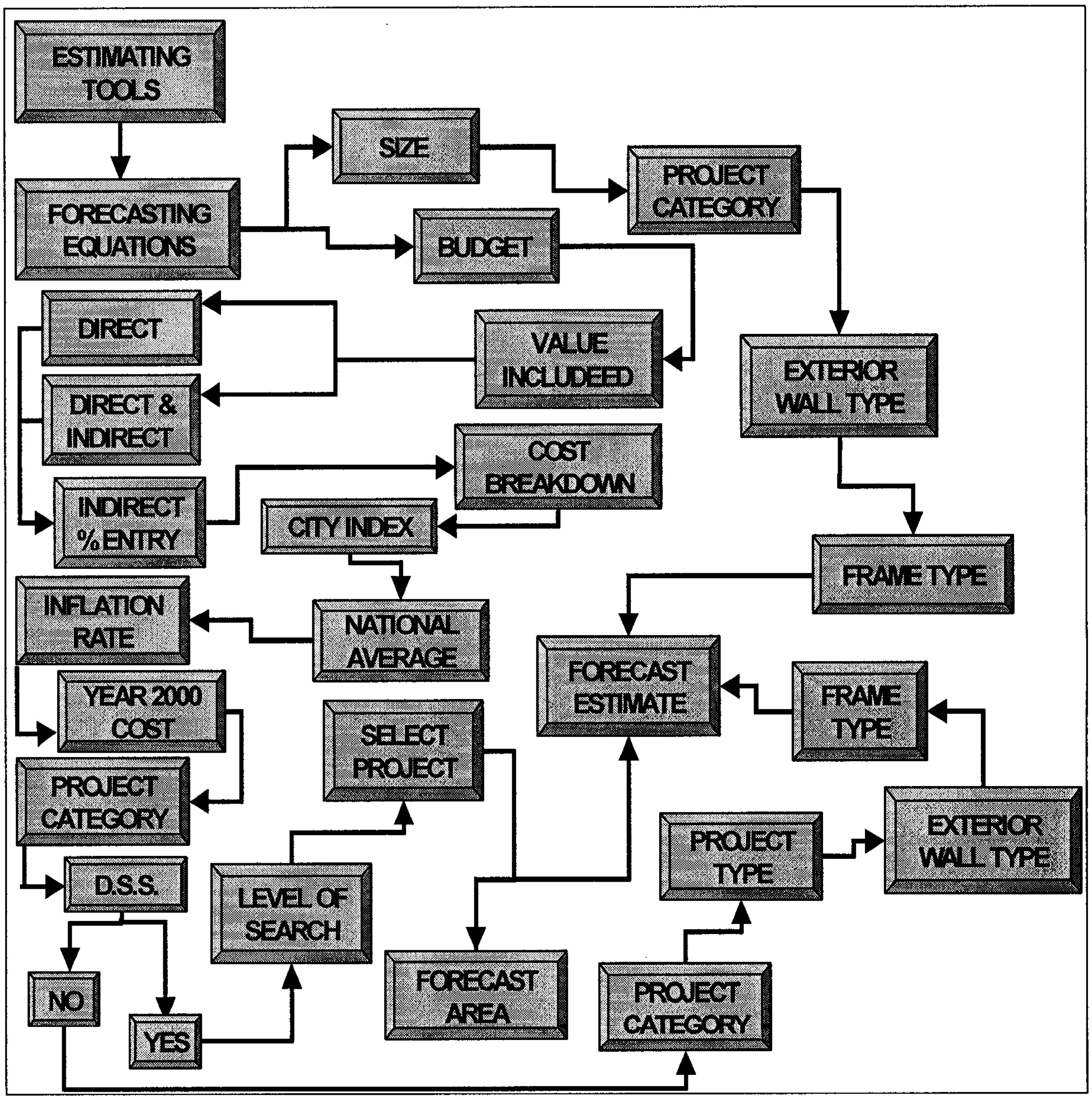


Figure 4.17 Workflow of Phase (5)

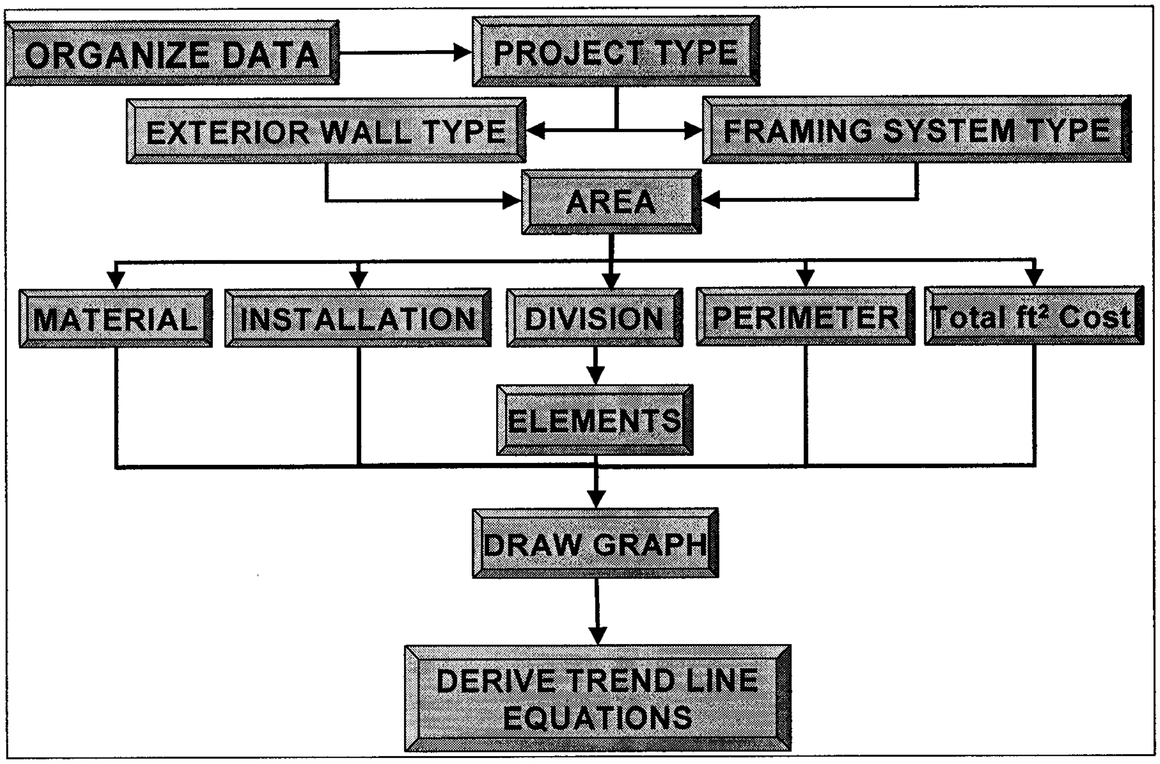


Figure 4.18 Phase (5) Process Flow Diagram

To start, all the cost data are organized into tabulated format depending on four parameters that are the project type, exterior wall type, framing system type and total floors area. The area is the key that links the perimeter value and all costs' data of material, installation, division/elements, and total square foot, and project costs. The forthcoming clauses present detailed explanations of the course of actions taken during the design of each of the three sub-modules respectively.

4.8.1 Forecasting Estimate Based on Size Entry Sub-Module

In this sub-module, cost data are classified and tabulated based on the total floors area and the square foot cost of each of the parameters mentioned in the foregoing paragraph as illustrated in Figures 4.19. On the other hand, the data for each division and its associated elements are organized and tabulated as percentages according to the total floors area as demonstrated in Figure 4.20.

Project Type:	Apartment 1-3 Story			
Exterior Wall Type:	Face Brick with Concrete Block Back-up			
Structure Framing Type:	Wood Joists			
S.F.Area	Material/S.F.	Installation	Total/S.F.	Perimeter
8,000.00	$41.61	$49.65	$91.26	213.00
12,000.00	$38.07	$44.41	$82.48	280.00
15,000.00	$36.64	$42.28	$78.93	330.00
19,000.00	$34.72	$39.28	$74.00	350.00
22,500.00	$34.01	$38.21	$72.22	400.00
25,000.00	$33.60	$37.62	$71.22	433.00
29,000.00	$32.67	$36.04	$68.70	442.00
32,000.00	$32.40	$35.64	$68.04	480.00
36,000.00	$32.02	$35.05	$67.07	520.00

Figure 4.19 Cost Data Organized Based on S.ft

Interior Construction

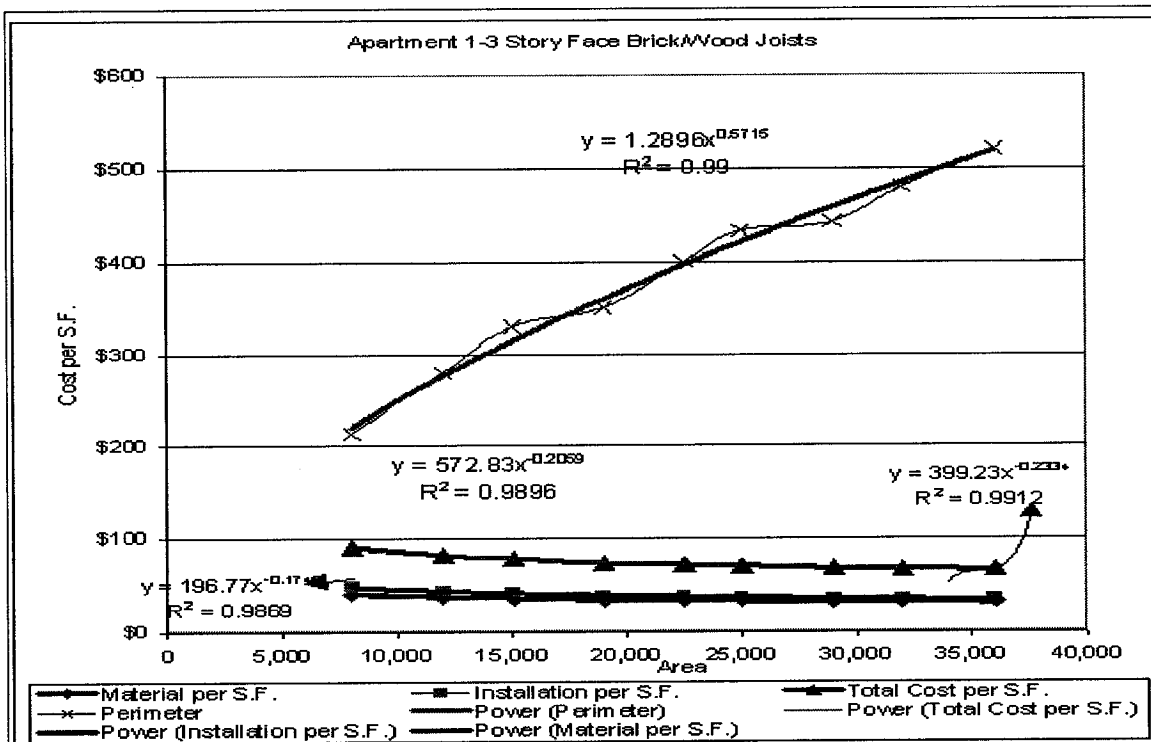
Exterior Wall Type: **Face Brick with Concrete Block Back-up**

Structure Framing Type: **Wood Joists**

S.F.Area	InteriorConst	DivElm6_1	DivElm6_4	DivElm6_5	DivElm6_6	DivElm6_7	DivElm6_9
8,000.00	23.30%	21.40%	26.85%	9.88%	19.80%	12.89%	9.08%
12,000.00	25.30%	21.37%	27.36%	9.87%	20.17%	13.13%	8.05%
15,000.00	26.20%	21.42%	27.56%	9.87%	20.31%	13.25%	7.69%
19,000.00	27.50%	21.23%	28.06%	9.78%	20.69%	13.46%	6.54%
22,500.00	28.00%	21.31%	28.24%	9.84%	20.87%	13.50%	6.33%
25,000.00	28.40%	21.16%	28.18%	9.79%	20.86%	13.55%	6.18%
29,000.00	29.00%	21.18%	28.66%	9.89%	21.18%	13.75%	5.52%
32,000.00	29.30%	21.17%	28.59%	9.78%	21.17%	13.69%	5.42%
36,000.00	29.60%	21.20%	28.76%	9.77%	21.26%	13.80%	5.24%

Figure 4.20 Division and Associated Elements' Data

Once all the related costs' data are organized into a set of tables, graphs are developed for each set of data using spreadsheets. Associated equations of the best-fitted lines are derived, as shown in Figure 4.21. All the derived equations are included into the sub-module to forecast the costs of the proposed project. Once the user selects the project type, exterior wall and framing system type the module will forecast the project's costs.



Parameter	**Equation**	R^2
Material	$Y = 196.77x^{-0.1746}$	**0.9869**
Installation	$Y = 399.23x^{-0.2884}$	**0.9913**
Total Cost	$Y = 572.83x^{-0.2069}$	**0.9896**
Perimeter	$Y = 1.2896\ X^{0.5716}$	**0.9900**

Figure 4.21 Trend Line Equations Derived Based on Size

Deriving all the needed equations would accomplish the design of this sub-module and accordingly we move to the design of the second one. Appendix (C) provides a list of the derived equations for this sub-module.

4.8.2 Forecasting Costs Based on Budget Entry Sub-Module

This sub-module's design is similar to the previous one except that the costs data are organized and stored based on the total cost and on the cost per square foot cost of each of the parameters mentioned in the previous paragraph. Figure 4.22 shows the cost data and Figure and 4.23 shows an associated graph.

Project Type:	Apartment 1-3 Story					
Exterior Wall Type:	Face Brick with Concrete Block Back-up					
Structure Framing Type:	Wood Joists					
S.F.Area	Total/S.F.	Total ($)	Material/S.F.	Total Material	Installation/S.F.	Total Installation
8,000.00	$91.26	$730,080	$41.61	$332,880	$49.65	$397,200
12,000.00	$82.48	$989,760	$38.07	$456,840	$44.41	$532,920
15,000.00	$78.92	$1,183,800	$36.64	$549,600	$42.28	$634,200
19,000.00	$74.00	$1,406,000	$34.72	$659,680	$39.28	$746,320
22,500.00	$72.22	$1,624,950	$34.01	$765,225	$38.21	$859,725
25,000.00	$71.22	$1,780,500	$33.60	$840,000	$37.62	$940,500
29,000.00	$68.71	$1,992,590	$32.67	$947,430	$36.04	$1,045,160
32,000.00	$68.04	$2,177,280	$32.40	$1,036,800	$35.64	$1,140,480
36,000.00	$67.07	$2,414,520	$32.02	$1,152,720	$35.05	$1,261,800

Figure 4.22 Data Organized Based on Total Costs

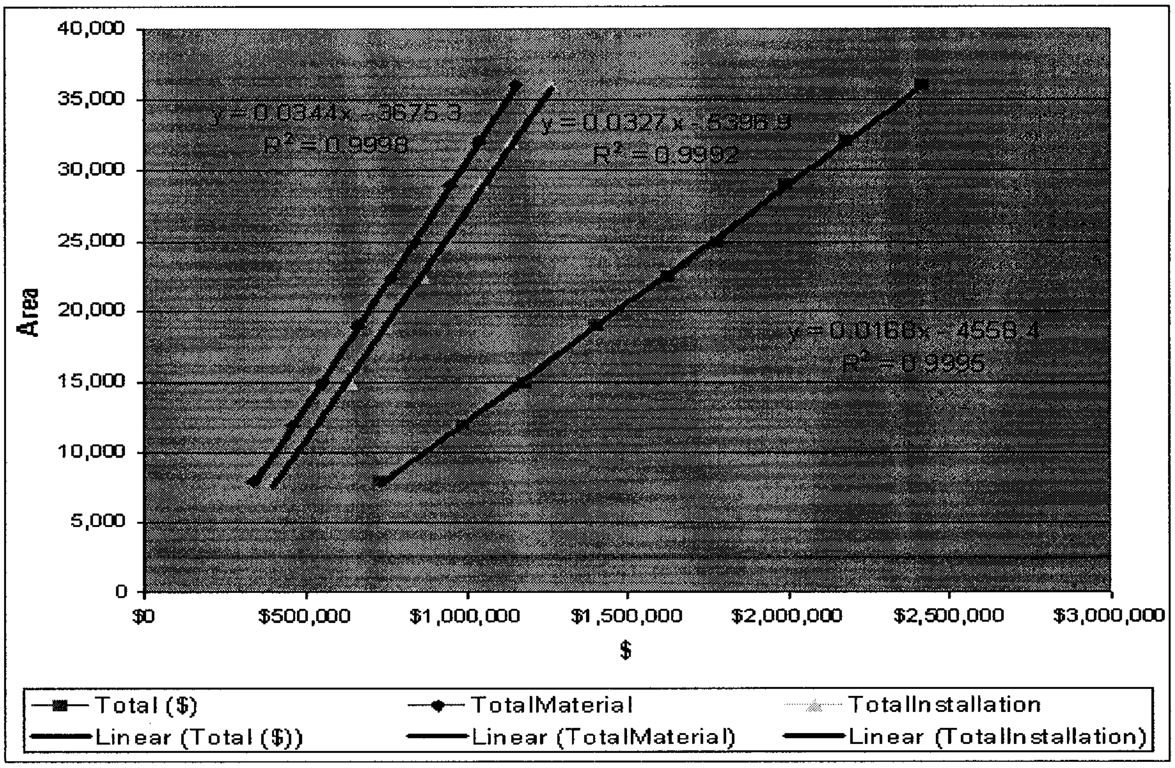


Figure 4.23 Trend Line Equations Derived Based on Budget

All necessary equations are derived and set into tabulated format as shown in Appendix (C). These equations are to be used to forecast the area of the proposed project and the estimated costs based on the budget entry. However in this case, the cost values included in this budget have to be clarified. If the entered budget includes direct and indirect costs, the sub-module calculates the value of these costs after the user inputs the indirect percentage values using equations [4.17] to [4.19].

Project Total Cost (Y) = Direct Construction Costs (X) + Indirect Costs [4.17]

$$\text{Indirect Cost} = X*(P+O+A+C)*(ST+1) = Y-X \quad [4.18]$$

Where,

P = Profit(%); O = Overhead(%); A = Architecture Fee(%); C = Contingency(%) and ST = Sales Tax(%)

$$X = \frac{Y}{[1+(P+O+A+C)*(ST+1)]} \quad [4.19]$$

Since all the derived equations are based on National Average costs of year 2000, the budget entered has to be adjusted accordingly. Thus, after the sub-module breaks down the entered costs, it adjusts them based on National Average costs using the following equation:

$$C_N = C_A\left(\frac{100}{I_A}\right) \quad [4.20]$$

Where C_A = cost in dollars for city A

C_N = national average cost in dollars

I_A = index for city A as percentage (user input)

Then it brings them back to year 2000 after the user inputs the inflation rate using the following equation

$$P = F\,(1 + i)^{-n} \qquad [4.21]$$

Where n = number of years between current year and year 2000

F = Direct Cost based on National Average Costs

P = Direct Cost at Year 2000

i = Inflation rate entered by the user

Thereafter, the user selects the project category, type, exterior wall, and framing types. Based on this combination of selection, the sub-module forecasts the area and cost estimate promptly.

On the other hand, in case the keyed-in budget includes only the direct costs, the sub-module calculates the indirect costs after the user enters their values. Afterwards, equations [4.2] to [4.7] are used by the sub-module for this matter, and the same procedures used in the previous paragraph are followed to forecast the area and the related estimate.

4.8.3 Decision Support System Based on Budget Entry Sub-Module

In this sub-module a Decision Support System (DSS) is to be designed in order to assist users in selecting the optimum project size within the data available in the database and its 3D-CAD drawing within their anticipated budget. In phase two, in order to store 3D-CAD drawings, a special database is designed, which the DSS uses in selecting the best-fit drawing based on the forecasted area. This research uses the Rule-Based Reasoning approach in the design and implementation of the DSS. The system contains a total of 70 rules related to the system functionality. These rules are divided into three groups as follow:

1. Wide, containing 20 rules
2. Intermediate, containing 20 rules
3. Narrow, containing 30 rules.

Figure 4.24 shows the structure of the Rule Base module and its groups. In addition, an explanation of the legend used in each component of the Rule Base is presented in Figure 4.25.

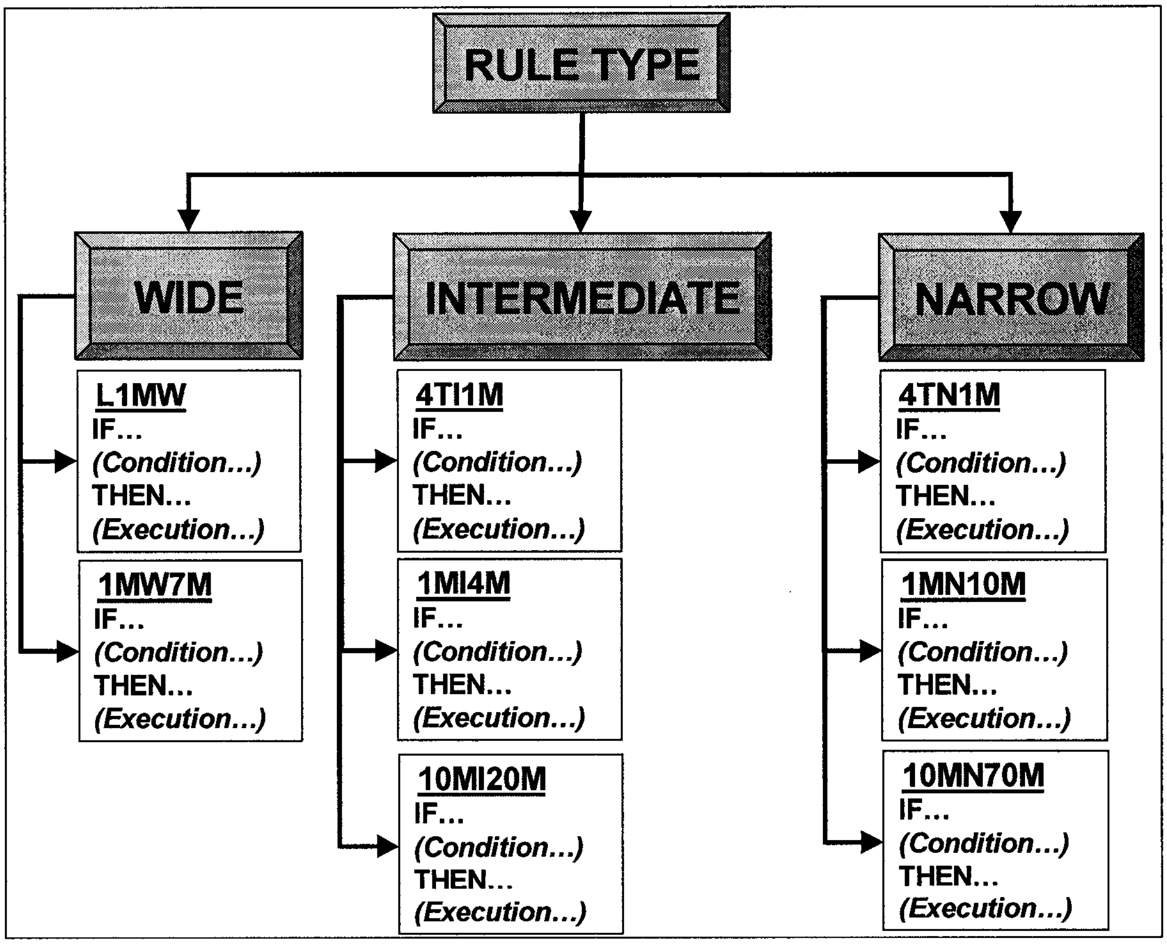


Figure 4.24 Rule Base Structure

A workflow process has been designed in order to identify the steps that this sub-module will execute as shown in Figure 4.26. The process begins by inputting the budget then selecting the rule type. The system automatically searches for the optimum project(s) that its/their direct construction costs rank within the budget

WIDE:

1. **L1MW: Less than 1 million dollars step 100,000**
2. **1MW70M: Between 1 and 70 million dollars step 100,000**

INTERMEDIATE:

1. **4TI1M: Between 40,000 and 1 million dollars step 1,000**
2. **1MI4M: Between 1 and 4 million dollars step 10,000**
3. **10MI70M: Between 10 and 70 million dollars step 50,000**

NARROW:

1. **4TN1M: Between 40,000 and 1 million dollars step 500**
2. **1MN10M: Between 1 and 10 million dollars step 1,000**
3. **10MN70M: Between 10 and 70 million dollars step 10,000**

Figure 4.25 Legend of the Rule Base Components

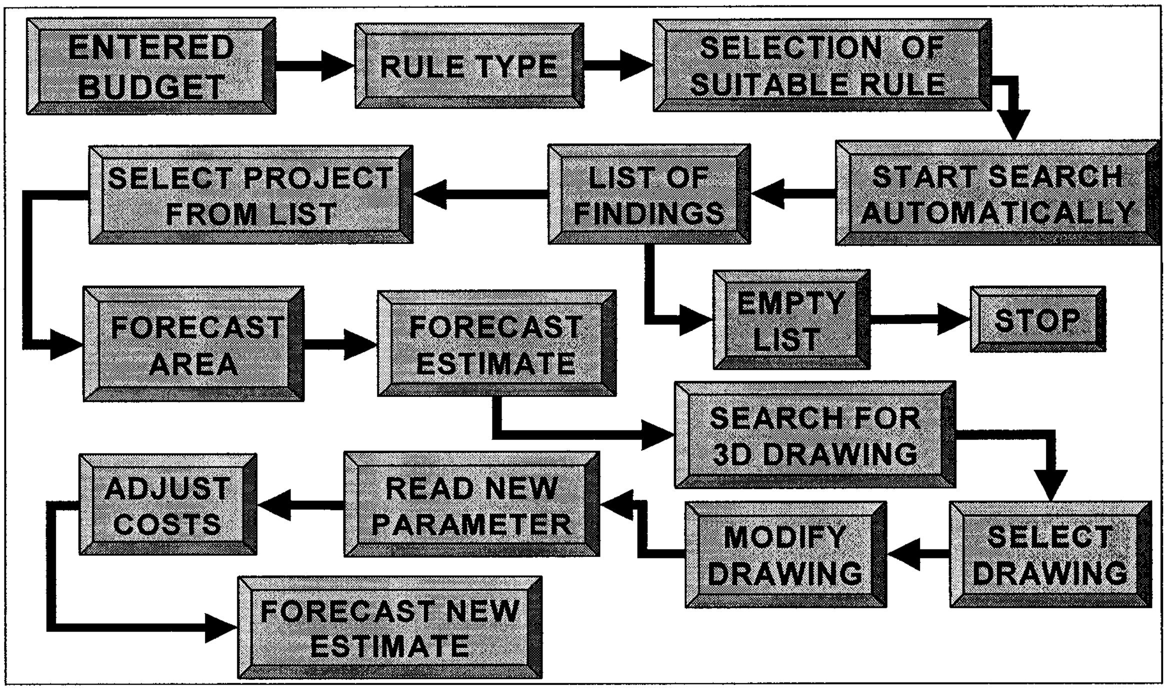


Figure 4.26 DSS Workflow Process

entered by the user. In case of an empty listing, the system stops the search until the user changes the rule type. In case a list is provided, a selection of the project is made, and, accordingly, the sub-module forecasts the area using the equations derived in paragraph 4.8.2. Once this value is accepted by the user, the sub-module forecasts the whole estimated costs using the same stated equations. Upon the user's request, the DSS selects from the specified database the most suitable 3D-CAD drawing, which it makes available to the user to animate and modify. Routed on the drawing's modification, the new parameters are read and written to the database and immediately a new estimate is forecasted and provided. Afterwards, the user can forecast the running costs of the proposed project and apply a sensitivity analysis as mentioned in previous paragraphs.

4.9 Conclusion

This chapter has described the development methodology of the system using available tools (equations, expressions, spreadsheet, relational databases, and programming languages). A procedure for developing the methodology is applied based on a group of identified system requirements. The system consists of the following five modules: 1) preliminary estimate module, 2) AutoCAD module, 3) global and parametric module, 4) LCC and sensitivity analysis module, and 5) Forecasting and DSS module. These individual modules are integrated through a database management system.

Detailed explanation of the designed modules and their tasks has been given. The expansion procedures are carried out using software applications known to the industry like AutoCAD, 3D Studio, MS Access, MS Excel, and Visual Basic.

CHAPTER FIVE

SYSTEM'S DEVELOPMENT PROCESS

5.1 Introduction

The phases of developing the system's methodology was discussed in the previous chapter. It dealt specifically with the conceptual design, architecture, data flow and workflows. It also discussed the derivation of sets of linear regression equations and expressions. Furthermore, the methodology included the assignment of 70 rules grouped in three different sub-groups to be incorporated into the Decision Support System. This chapter describes the physical implementation of the system. It exhibits the process practiced in developing and implementing the computer system that comprises all five modules.

5.2 Database's Development (Phase 1)

The development of this phase comprises the transformation process from conceptual to logical design by mapping the data model and executing the physical design and then deriving the internal schema. The data model mapping consists of transferring all the components of the conceptual schema into related relations. This is accomplished by using the ER-to-Relational Mapping approach in which a relation is created for each entity type including all its simple attributes. Each multi-valued and composed attribute is transferred into a relation including its attributes and the primary key of the entity that it is related to. Each weak entity is then translated into a separate relation holding its attributes and the primary key of its prime entity. A separate relation is then created for each sub-class and many-to-many relationship including the corresponding attributes. Figure 5.1 illustrates the data model mapping for the conceptual schema of the parametric cost estimate database shown in Figure 4.5 (Chapter Four). The entire data model mapping for all the databases being finished, the physical design can then be started. This is a DBMS specific step where all the computer work is performed. For each relation of the data model mapping a table is created in the database and each column in the table presents an associated attribute. The databases' design is considered separately in the succeeding paragraphs.

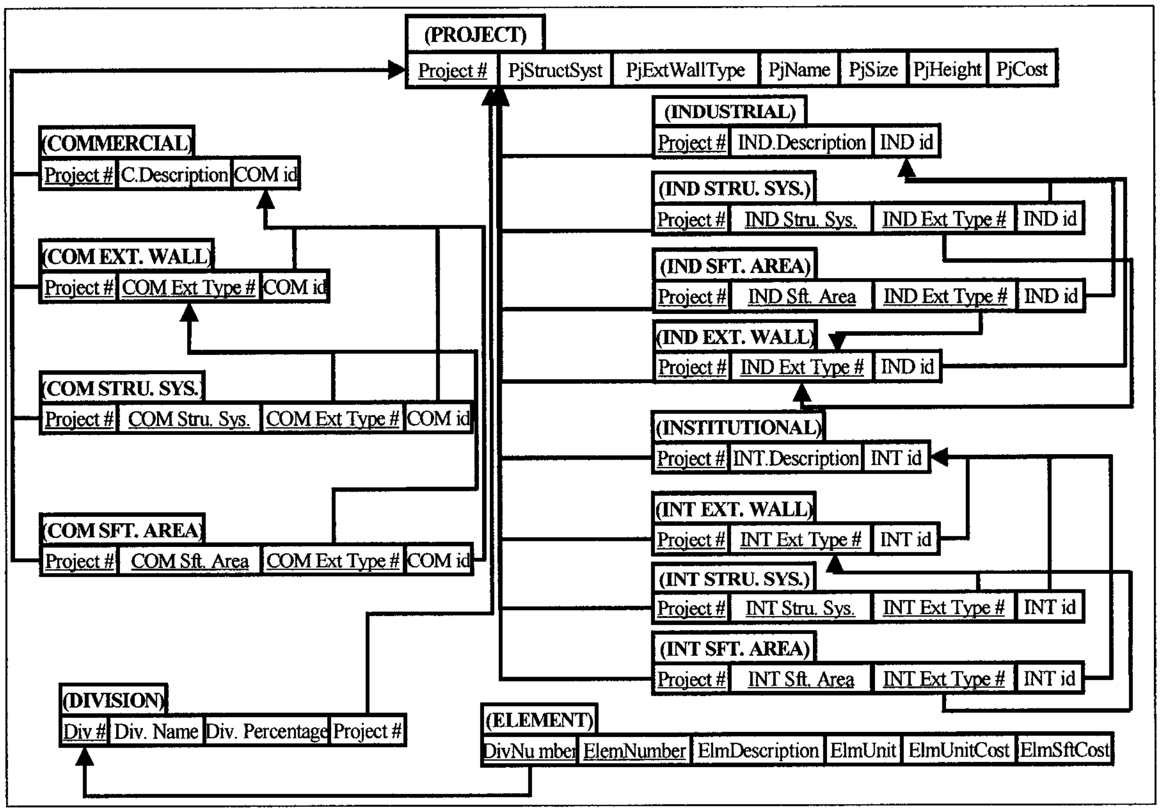


Figure 5.1 Data Model Mapping

5.2.1 Preliminary Databases and Module

The components of these databases are incorporated from the Entity Relationship Diagrams as follows: Project, Cost Source, Division (Component, elements), and City. The data source used is based either on own cost data (industry) or R. S. Mean's publications using both WBS (Masterformat and Assembly) with some modifications made for design purposes. To design these databases the following three major sequential steps are performed:

a) Step One

The data pertinent to these databases being selected, each division (component) and its associated sub-division (sub-component) and items (elements) have to be assigned a unique ID number as identification. This identification is important because it eliminates redundancies, conflicts, and duplications. Such numerical identification also speeds up the process of retrieving desired data. Thus, the numbering system used by R. S. Means is considered the base of the system used in these databases. This numbering system consists of ten-digit numbers partitioning each division into subdivision, medium scope, major classification, and individual line item number for the Masterformat WBS. On the other hand, assembly division, Means subdivision, Means major classification and Mean individual line number divide the Assembly WBS, as shown in Figures 5.2 and 5.3 respectively.

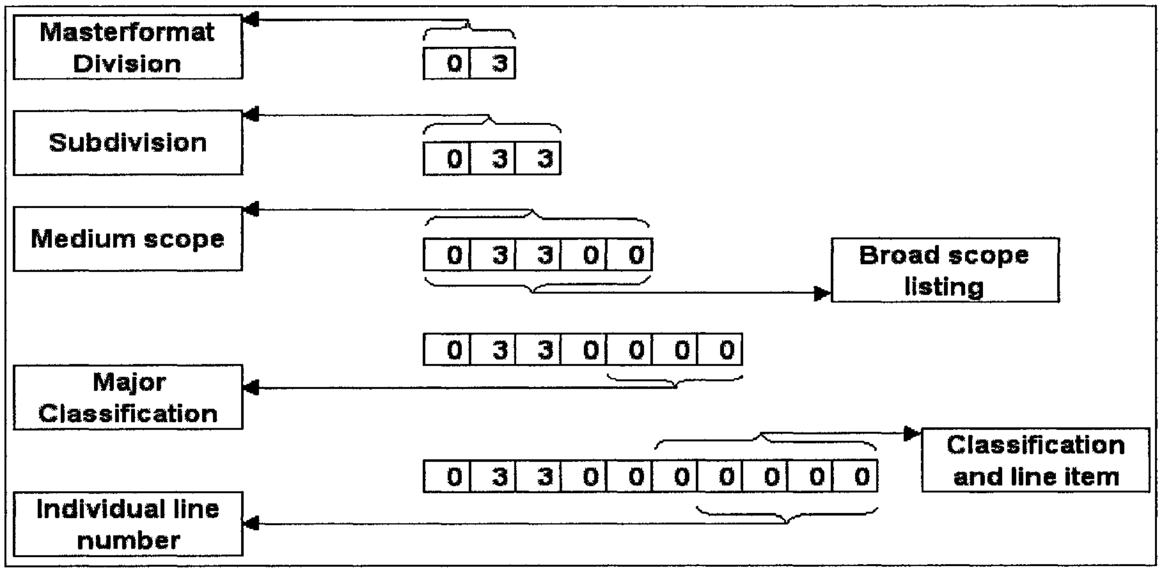


Figure 5.2 Numbering Systems for Masterformat WBS *(after R. S. Means)*

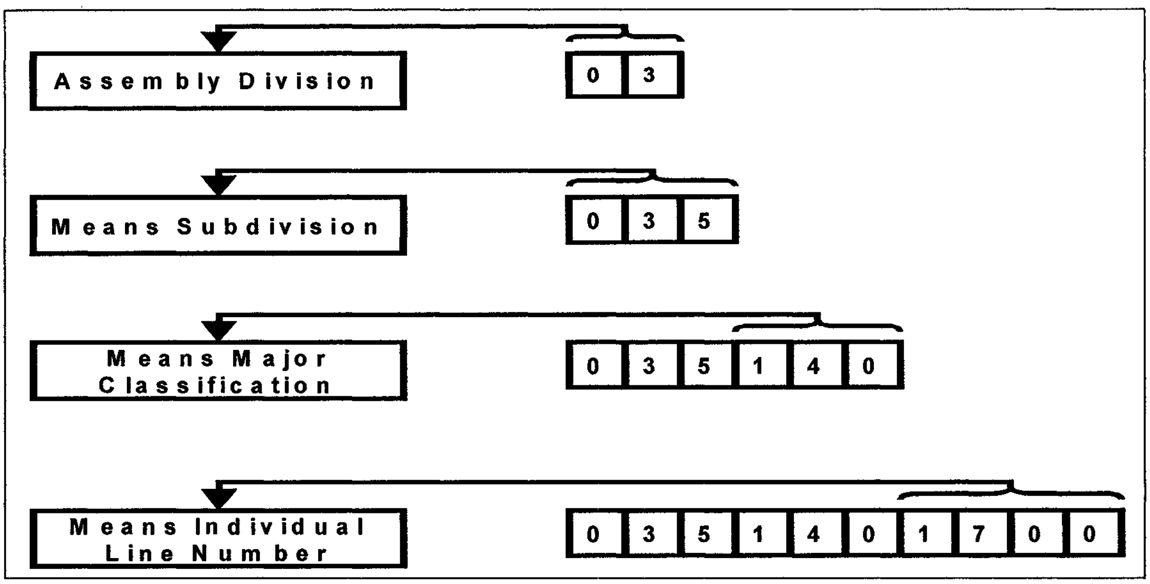


Figure 5.3 Numbering Systems for Assembly WBS *(after R. S. Means)*

By doing so, the user is able to manipulate and update the stored data easily and flexibly.

b) Step Two

Having identified the numbering system for each division and having associated line items for both work breakdown structures, tables need to be established. Generally, a relational database is composed of collections of tables that accommodate grouped data. Although data entry is the most time consuming process of the system development, each division and its interrelated line items are entered into two separate tables. A unique identifier links these two tables through (1:1) or (1:M) relationships. The related tables are named after the name of each division with an abbreviation showing the unit used. Besides these main tables, sets of vacant tables are designed and made ready for the user to utilize when building the items take-off list. In addition to other tables used to enter project information, units' type, data source type, etc. Figures 5.4 and 5.5 show the design view of one of these main tables and its relationships.

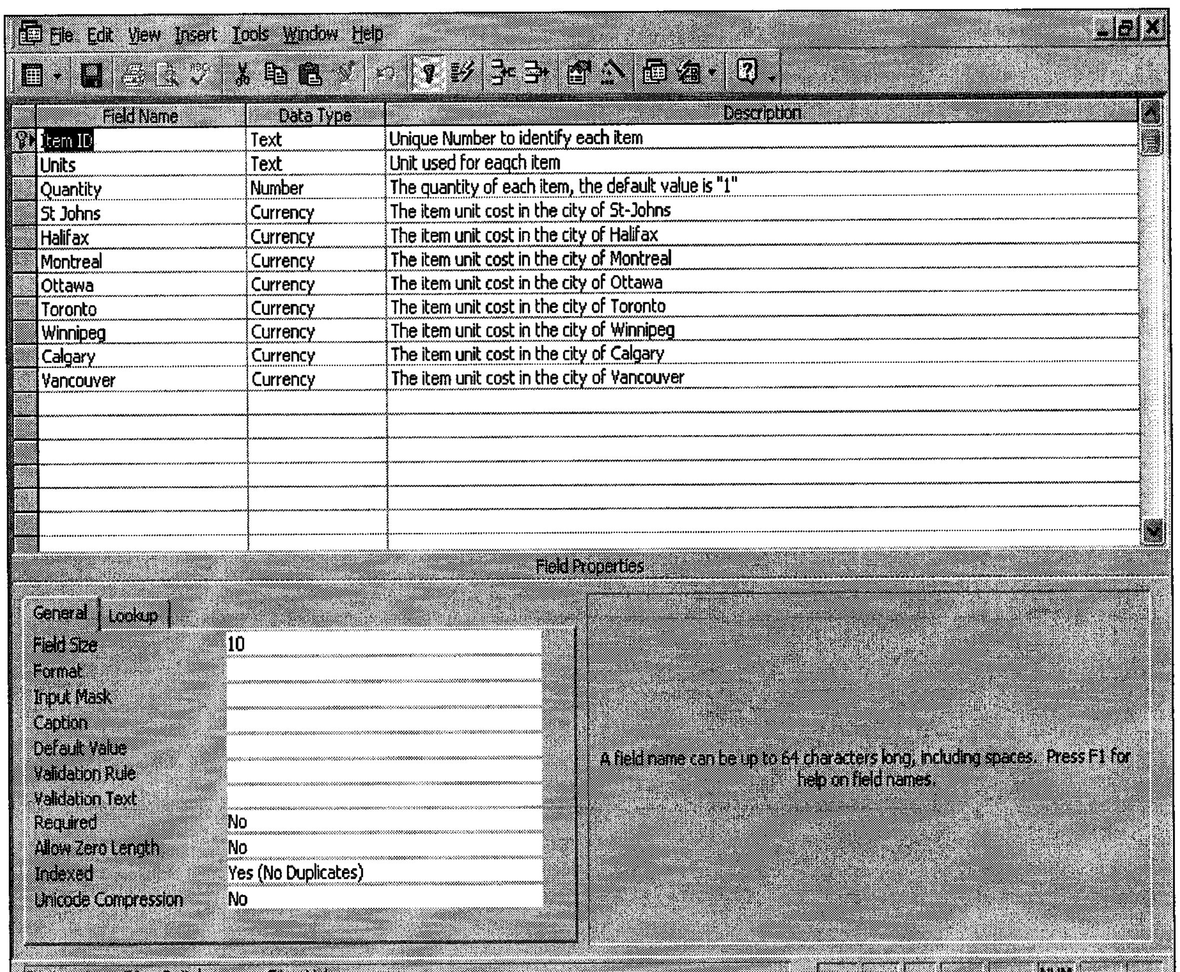


Figure 5.4 Design View of One of the Main Tables

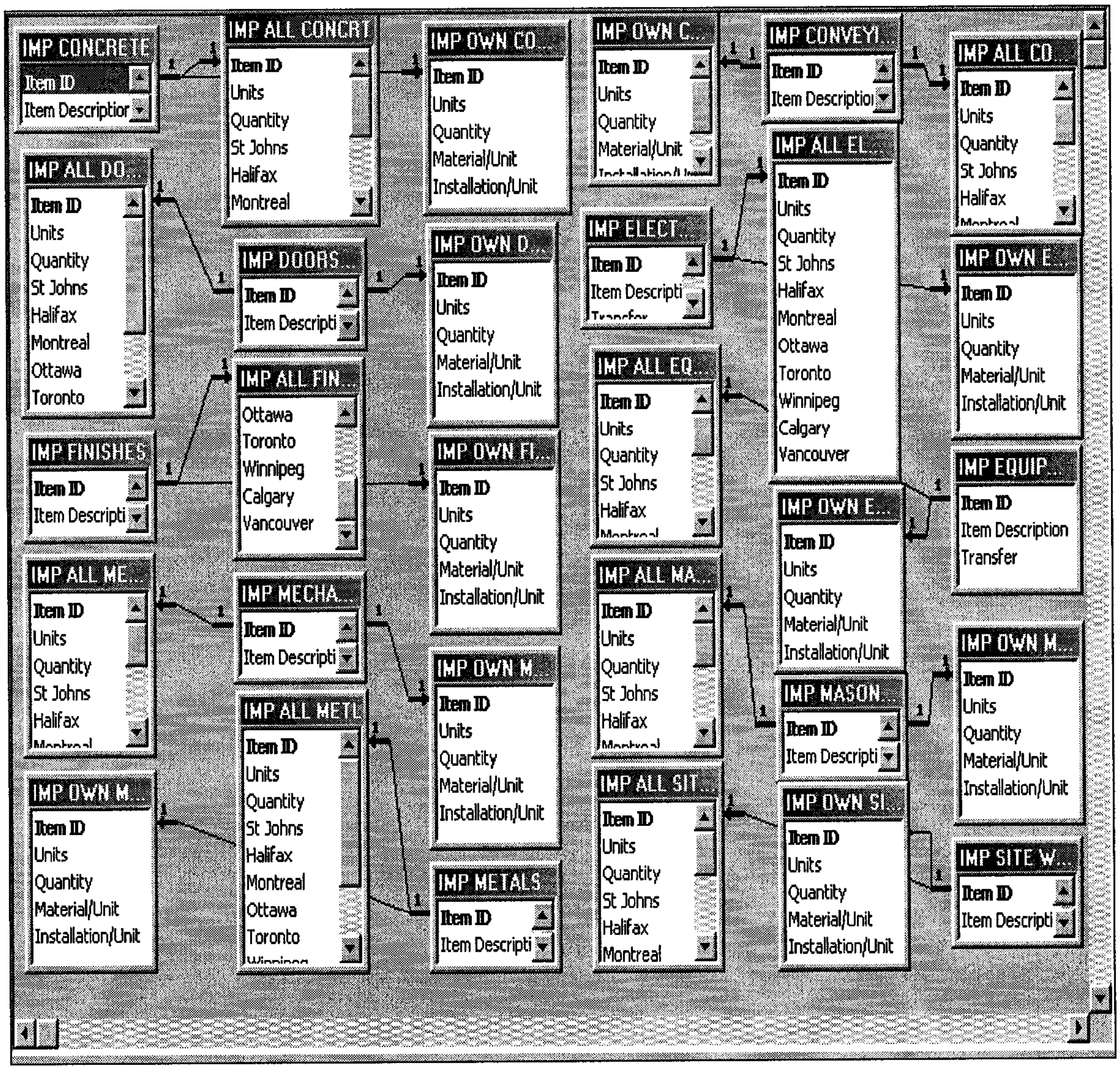


Figure 5.5 Preliminary Estimate Database Tables' Relationships

Due to their rigidity, tables do not allow data manipulation. Thus, sets of queries are utilized for this purpose. Expressions are used in all these queries in order to perform all the necessary calculations. All these queries are based on one or more related tables, and each one of them is specified to one division in accordance to the data source. Appendix (C) provides samples of the tables and queries used in the development of this database.

c) Step Three

After all the appropriate data are stored in sets of tables and queries, the preliminary estimate module design is carried out. Since the goal of designing this module is to deliver a tool that comprises clearness, simplicity, and user friendliness, sets of series of forms are designed in a way that each series represents the divisions of the selected WBS in a specific unit and city. Figures 5.6 and 5.7 illustrate forms based on Masterformat and Assembly WBS respectively.

Item ID	Item Description	Units	Unit Price	Quantity	Total
0310000000	FORM WORK FOR CONCRETE			1	
0311000000	SUBSTRUCTURE				
0311000005	Formwork, Strip (Wall) Footings, Leveled Footings	SF	$4.60	2582	$11,877.20
0311000010	Strip (Wall) Footings, Stepped Footings	SF	$4.74	11	$52.14
0311000015	Formwork for Spread (Column) footings, Column Footings	SF	$4.60	1582	$7,277.20
0311000020	Spread (Column) footings, Pile Caps	SF	$4.46	20	$89.20
0311000025	Spread (Column) footings, Raft Foundations	SF	$5.40	1	$5.40
0311000030	Formwork Foundation Walls and Grade Beams, Not exceeding 12' high, Concealed Finish	SF	$4.44	19528	$86,704.32
0311000035	Foundation Walls and Grade Beams, Not exceeding 12' high, Exposed Finish	SF	$5.10	22	$112.20
0311000050	Trench and Pit Formork	SF	$2.00	56	$112.00
0311000060	Formwork for Slab on Grade's Stairs	SF	$3.00	25	$75.00
0311000065	Formwork for Loading Deck Platforms	SF	$4.00	87	$348.00
0311000070	Slab depression Bulkheads	SF	$10.00	177	$1,770.00
0311000075	Form Pockets @ Steel Column Bases	units	$50.00	129	$6,450.00
0311000100	STRUCTURE				
0311000105	Multiple uses (minimum 4) 8 floors or more, Flat plate slab concealed finish	SF	$4.34	1	$4.34
0311000110	Multiple uses (minimum 4) 8 floors or more, Flat plate slab Exposed finish	SF	$4.74	1	$4.74

Description: Formwork Foundation Walls and Grade Beams, Not exceeding 12' high, Concealed Finish

Item ID: 0311000030 Units: SF Unit Price: $4.44 Quantity: 19528.00 Total: $86,704.32

Clear List

Figure 5.6 Sample of the Forms Based on Masterformat Divisions

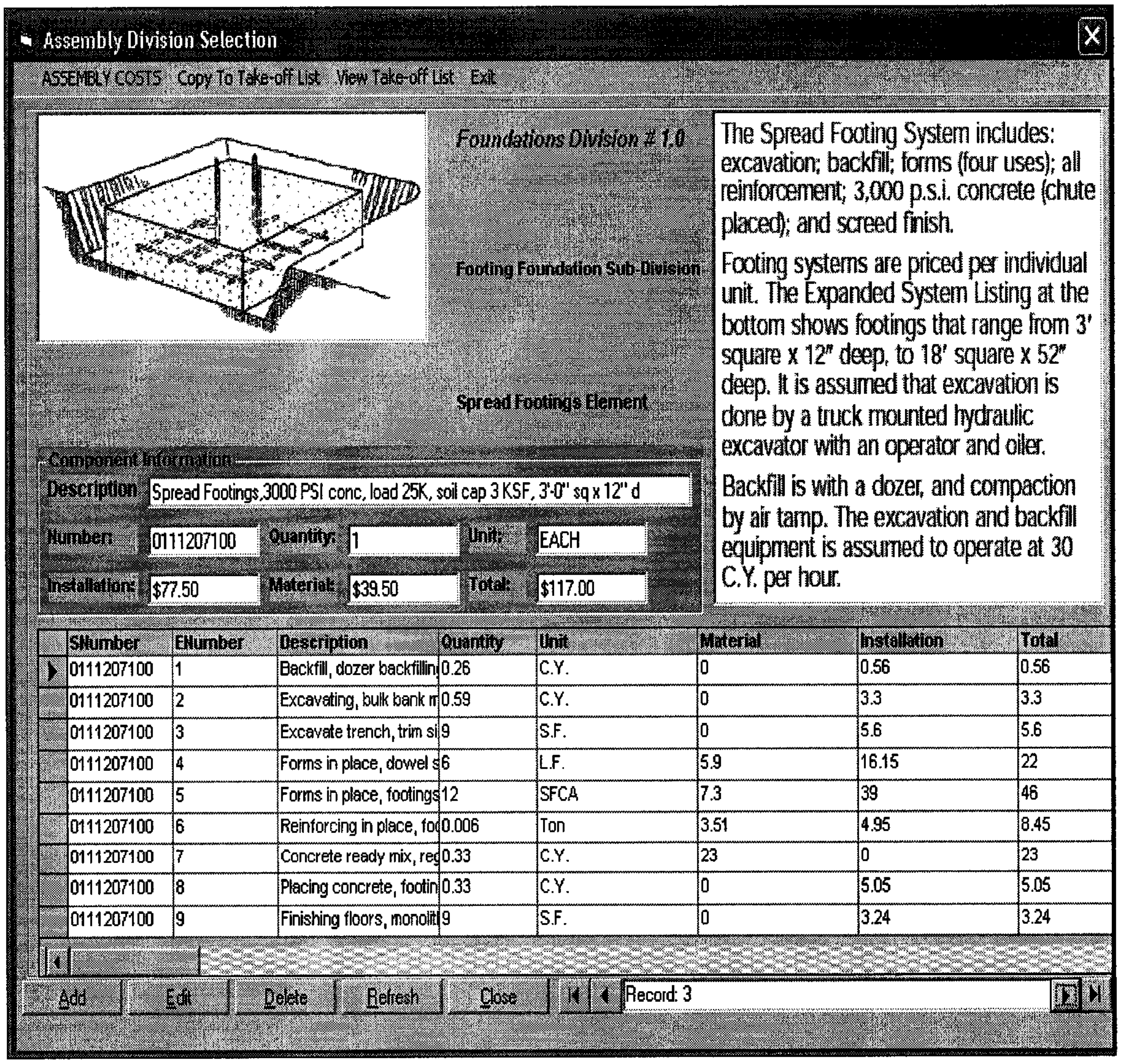


Figure 5.7 Sample of the Forms Based on Assembly Divisions

Each of these forms incorporates sets of command buttons for the user to instruct the module to execute required tasks and calculations. These tasks and calculations include, copying selected items to take off list, clear the list, view the take off list, records manipulation, exiting the form, selecting another division and so on. Figures 5.8 and 5.9 explain the role of each button depending on the chosen WBS.

To build the take off list, selected items are copied to a special form, which is designed for this purpose. At any time the user is willing to see the take off list and acquire the total sum of the copied line items in that list as displayed in Figures 5.10 and 5.11.

Moreover, the user has the option of entering his/her own cost data (industry data) according to his/her estimating requirements. For this reason, series sets of

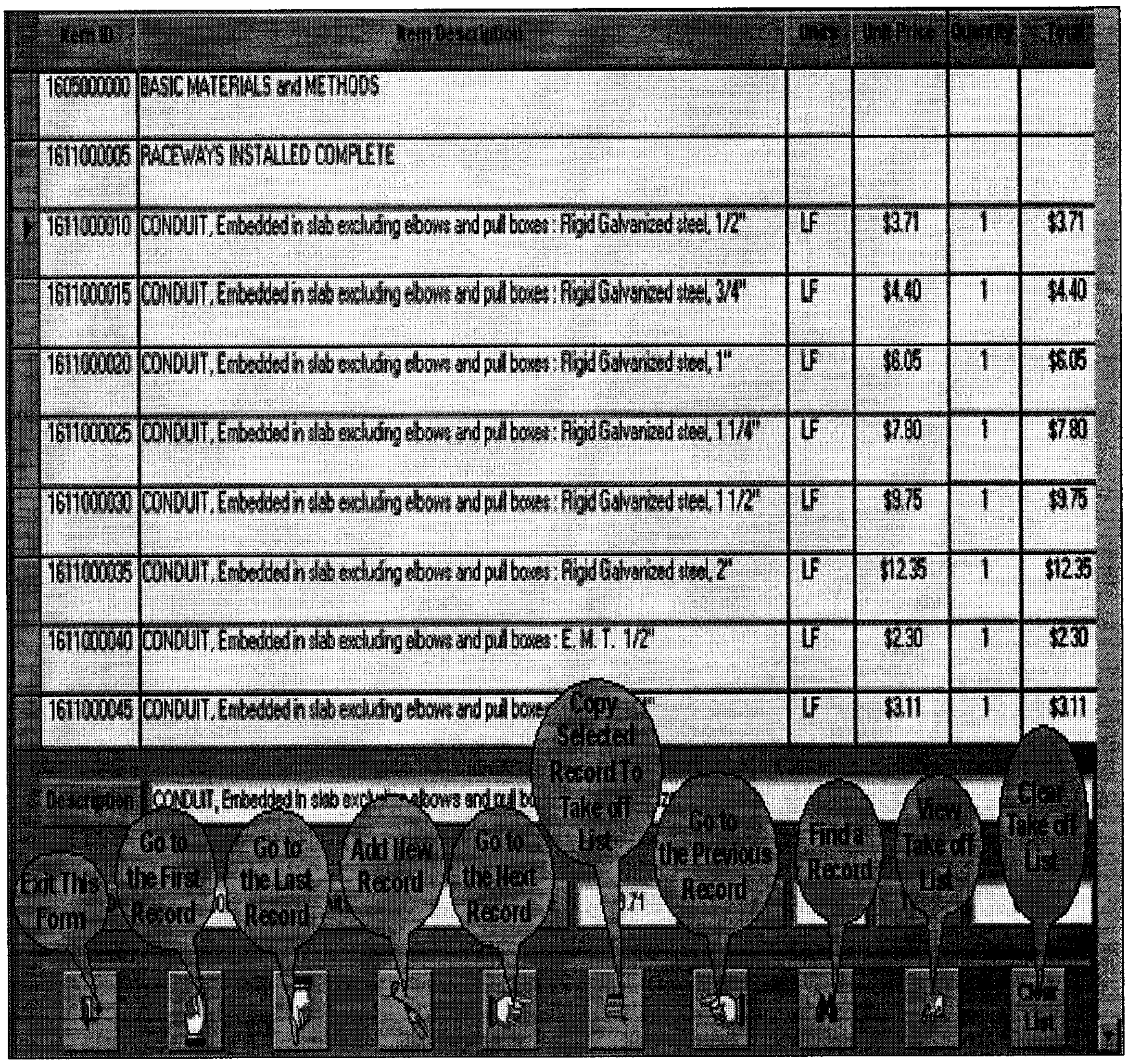


Figure 5.8 Incorporated Commands For Masterformat Forms

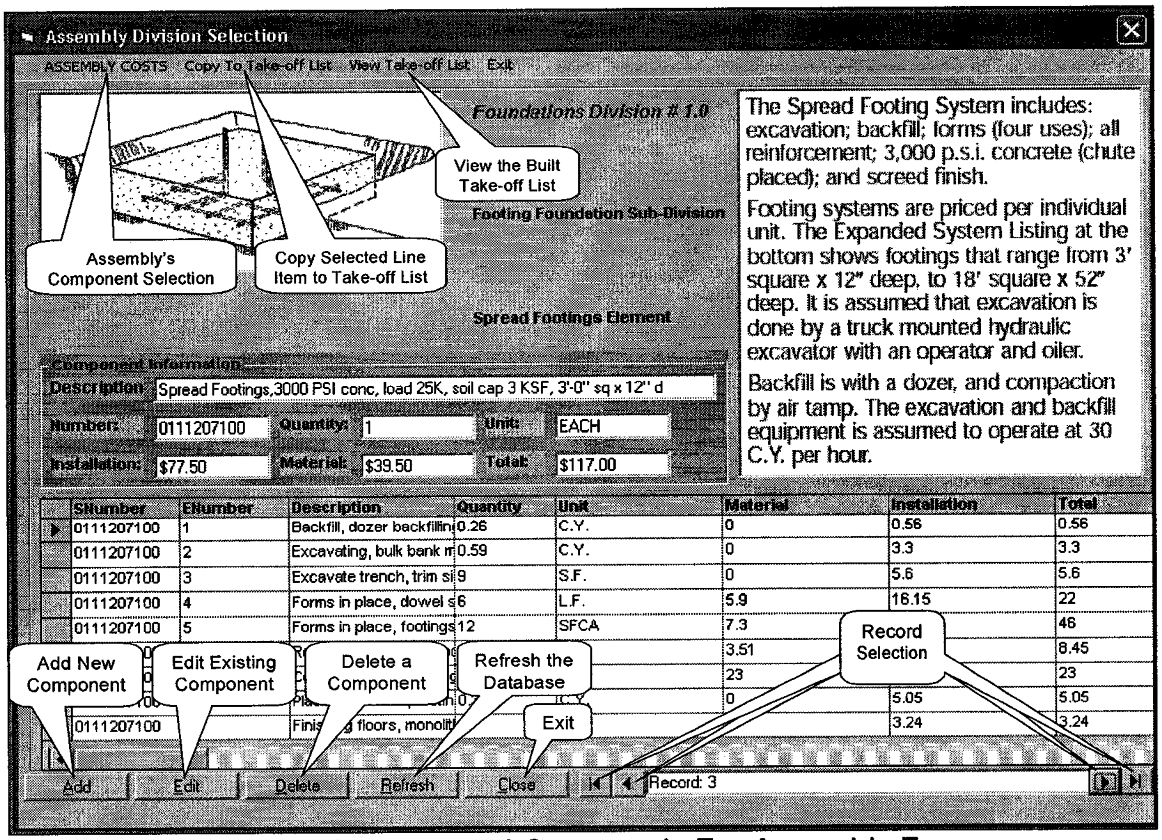


Figure 5.9 Incorporated Commands For Assembly Forms

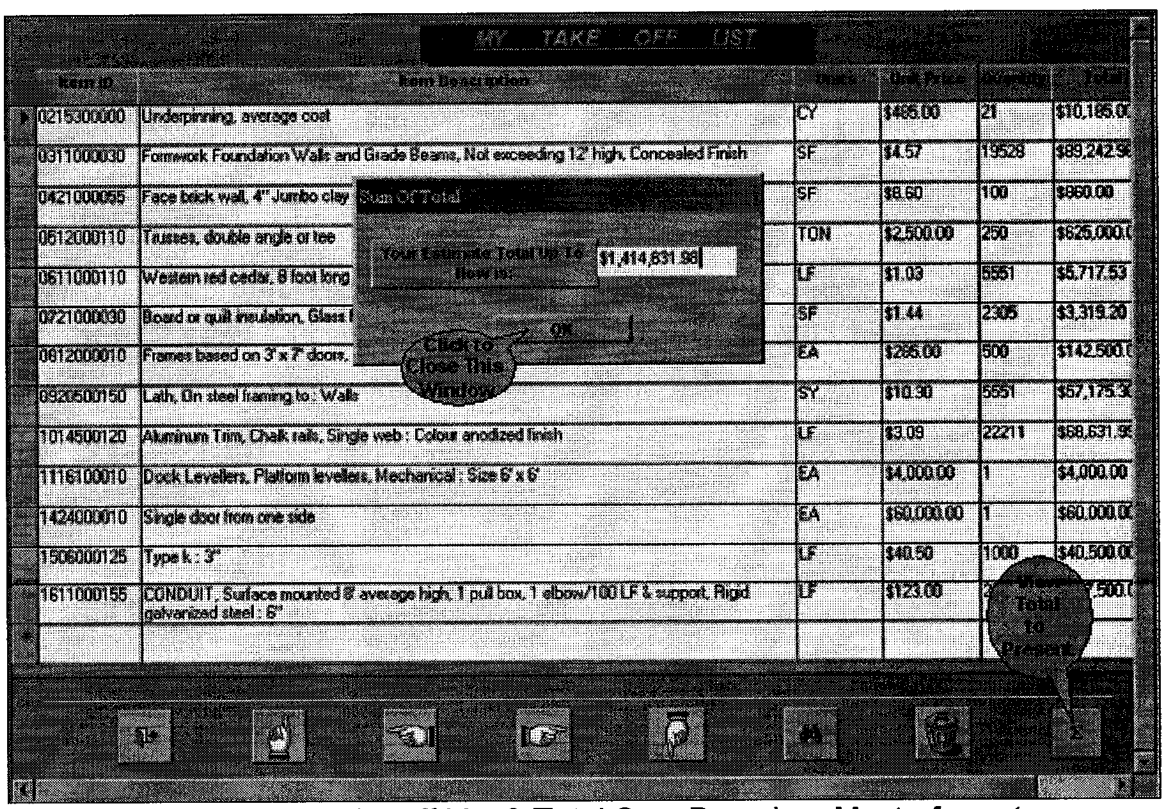


Figure 5.10 Take-off List & Total Sum Based on Masterformat

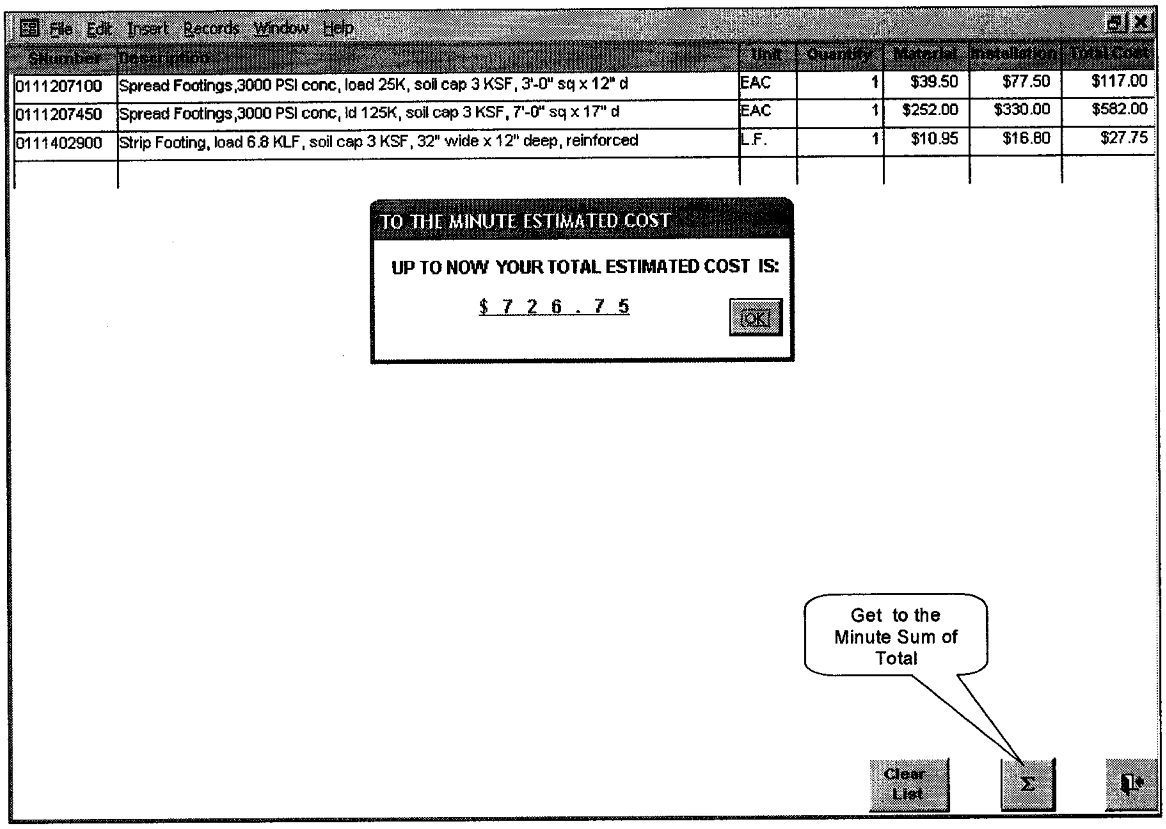
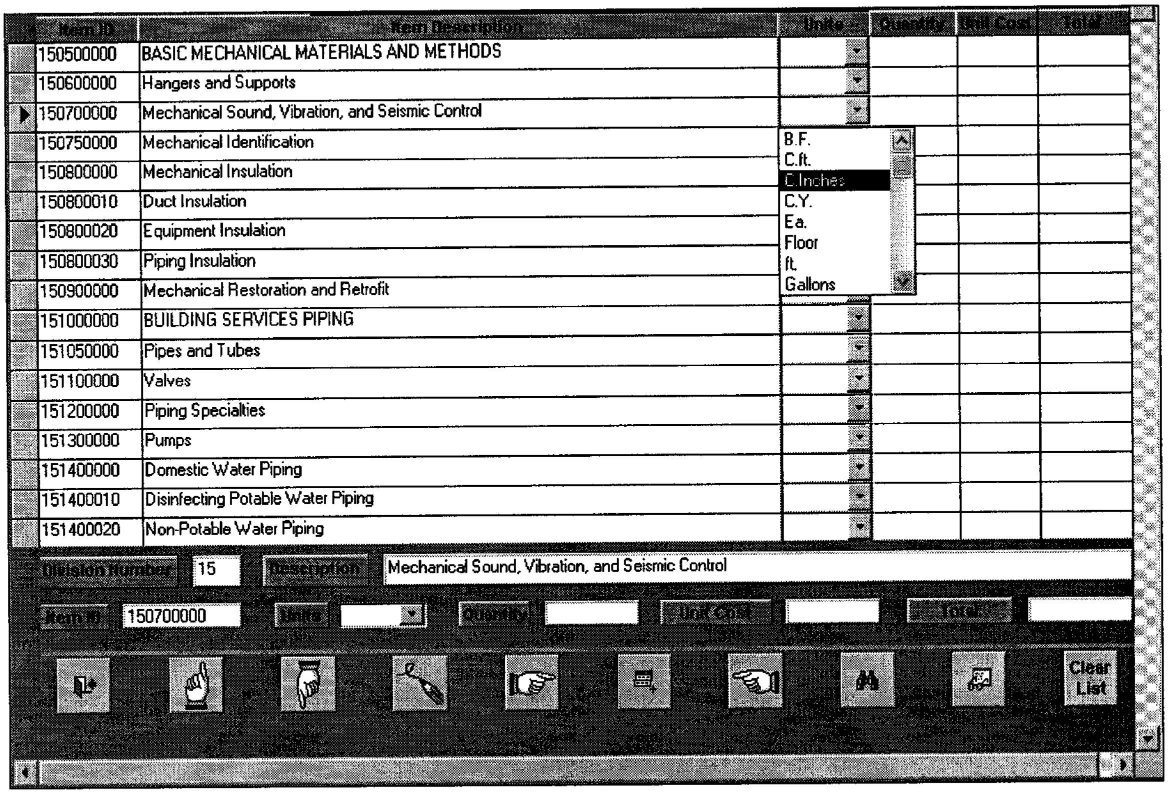


Figure 5.11 Take-off List & Total Sum Based on Assembly

forms are designed where no cost data is supplied yet the user can choose the units associated with each entered line item. Figure 5.12 gives a sample of these forms. Afterwards, the groups of queries linked to these forms perform all the necessary calculations. These forms are outfitted with the same command buttons and their executed events as are the published data forms. Likewise, the same design and options of the take off list forms are also readied for this case.



Item ID	Item Description	Units	Quantity	Unit Cost	Total
150500000	BASIC MECHANICAL MATERIALS AND METHODS				
150600000	Hangers and Supports				
150700000	Mechanical Sound, Vibration, and Seismic Control				
150750000	Mechanical Identification	B.F.			
150800000	Mechanical Insulation	C.ft.			
150800010	Duct Insulation	C.Inches			
150800020	Equipment Insulation	C.Y.			
150800030	Piping Insulation	Ea.			
150900000	Mechanical Restoration and Retrofit	Floor			
151000000	BUILDING SERVICES PIPING	ft.			
151050000	Pipes and Tubes	Gallons			
151100000	Valves				
151200000	Piping Specialties				
151300000	Pumps				
151400000	Domestic Water Piping				
151400010	Disinfecting Potable Water Piping				
151400020	Non-Potable Water Piping				

Figure 5.12 Sample Form for Own Cost Data

Subsequently, to facilitate the selection of the course of action for the WBS divisions (components) all the mentioned forms that incorporate these divisions are linked to a single form depending on the desired Canadian city. Figures 5.13 and 5.14 exemplify this type of form for the city of Montreal for both WBS. In a correlated manner, all the other cities' divisions are listed in forms similar to the one shown in Figures 5.13 and 5.14.

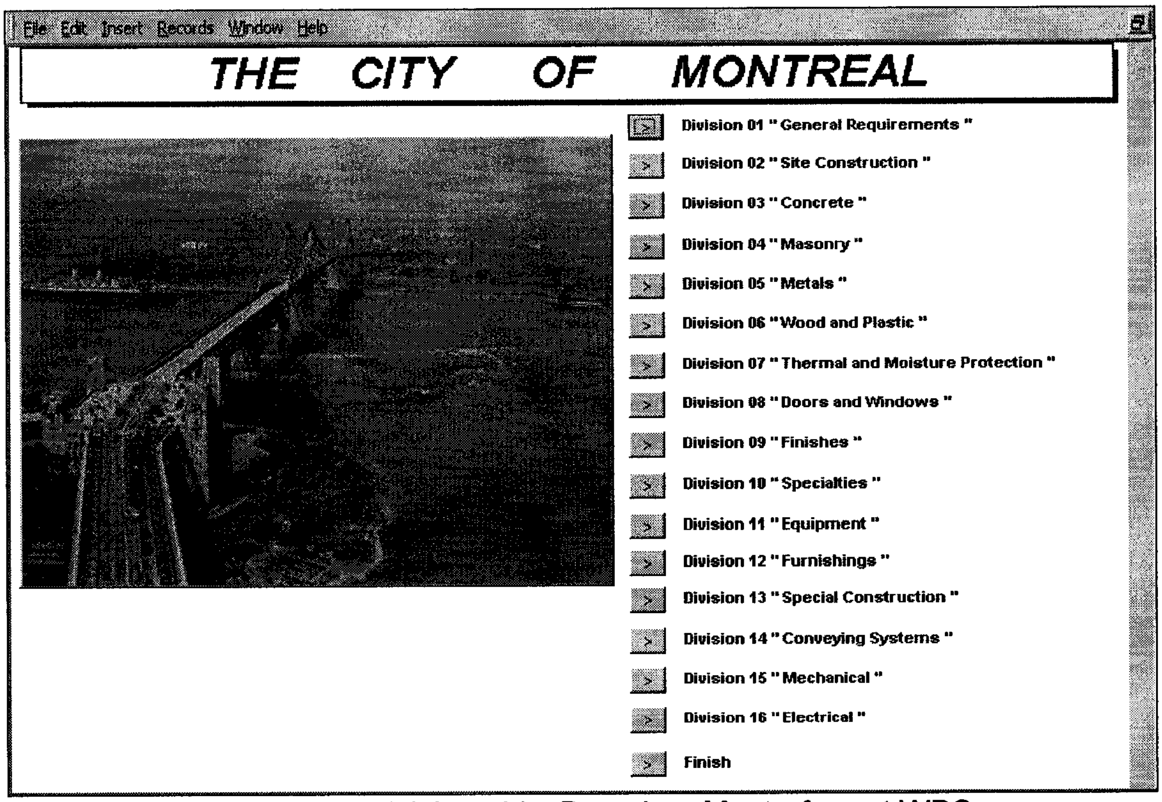


Figure 5.13 Divisions List Based on Masterformat WBS

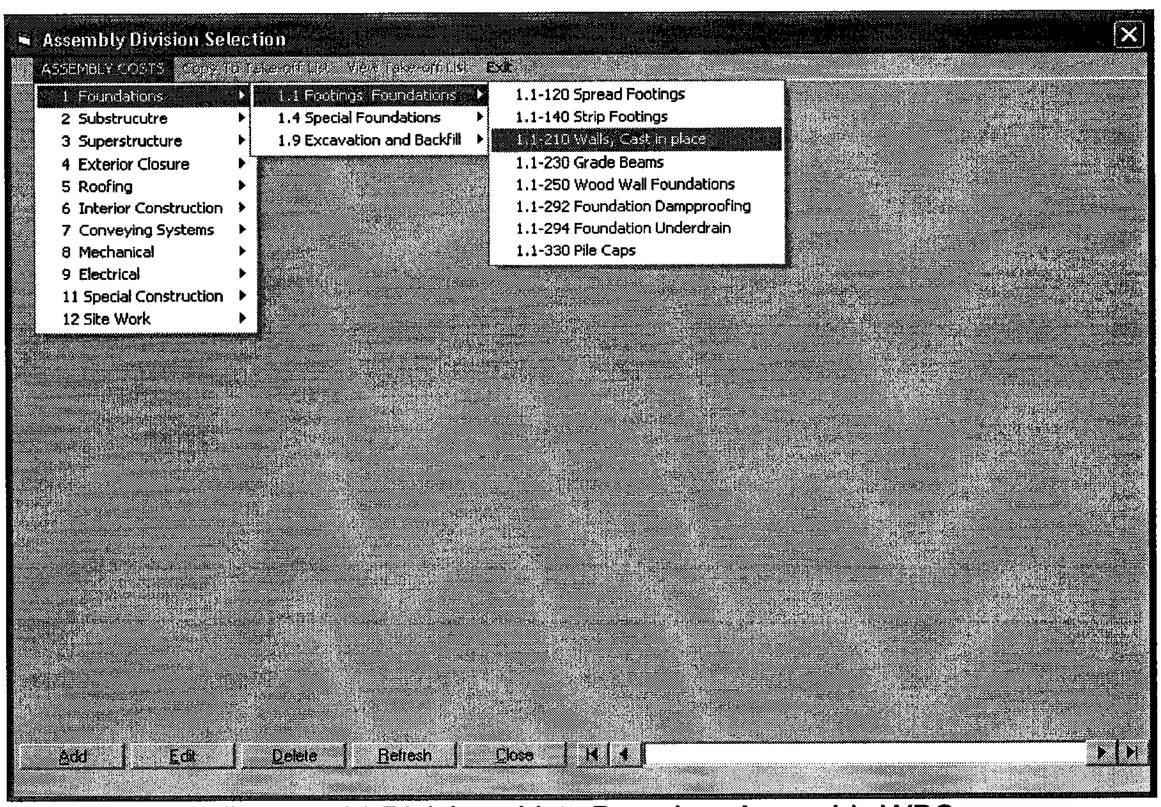


Figure 5.14 Divisions Lists Based on Assembly WBS

As soon as the user finishes the selection process of the required line items from each division, the module asks for entering Indirect Costs. Customized values are inherited in the module but the user can change them if needed as illustrated in Figure 5.15.

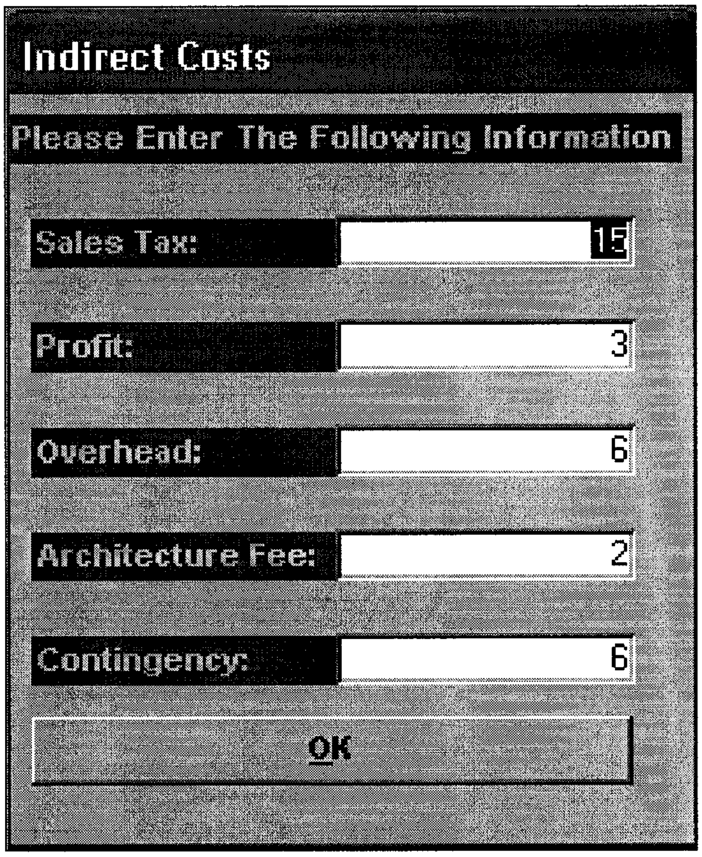


Figure 5.15 Customized Indirect Cost Values

Immediately after modifying the supplied indirect costs values and after clicking the "OK" button, the module displays a dialog form asking the user to select the desired type of output report from a list of four different types. These output reports can be either graphical (Pie or Bar Chart) or Tabulated (Detailed or Summary). Figure 5.16 exhibits this selection. Samples of these reports are better displayed in Chapter Six (System Performance) by using a case study. This would fulfill the preliminary databases and module development process.

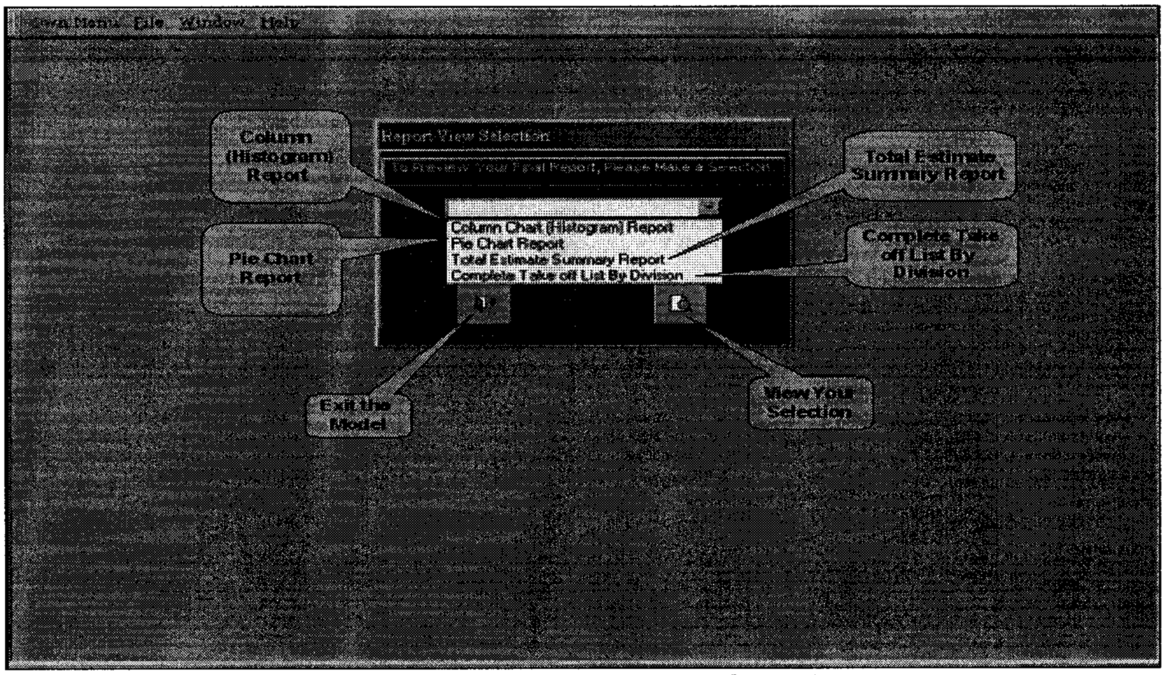


Figure 5.16 Output Reports' Selection

5.2.2 AutoCAD External Database

This database is designed and developed in such a way that it is linked to 3D CAD drawings. The AutoCAD module is able to write to it the read parameters from the drawing. This database consists of two tables, which are created for this purpose. The first, named "Polyline", accommodates the area and height of each floor while the second, named "Perimeter", stores the perimeter of the building. The tables' fields name, type, and size are represented in Tables 5.1 and 5.2 respectively.

Table 5.1 Polyline's Fields Name, Type, and Size

Field Name	Field Type	Field Size
Handle	Text	50
Area	Number	Double
Thickness	Number	Double
Color	Text	50

Table 5.2 Perimeter's Fields Name, Type, and Size

Field Name	Field Type	Field Size
Perimeter	Number	Double

Figure 5.17 exhibits the design view of the abovementioned “Polyline” Table.

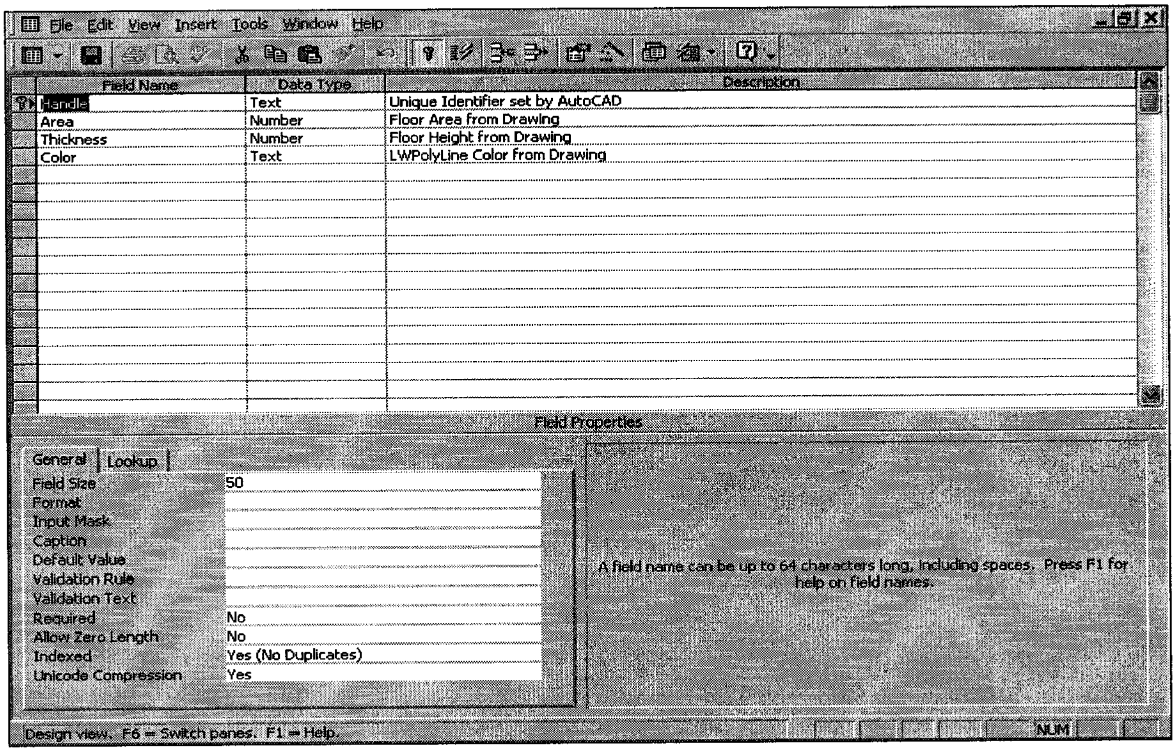


Figure 5.17 Design View of Table (1) in AutoCAD Database

5.2.3 Parametric Database

This is one of the major parts of this research. It utilizes the integration of many applications so that data is interrelated and exchanged between them. The ER-Diagram shown in Figure 4.5 (Chapter Four) is the source in which the components of this database are detected. The database comprises sets of previously executed projects gathered from R. S. Means’ publications data for the year 2000 based on both WBS. With the intention of simplifying and easing the development of these databases, three sequential steps are considered:

a) Step One

Data on a total of 70 projects is stored in the database, these projects are divided into three types: “Commercial”, “Industrial” and “Institutional”. They combine

3,735 categories depending on the project size, exterior wall and structure framing types and every category has 27 elements. Therefore, a numbering system is designed and implemented to facilitate and quicken the data retrieval process. The designed system consists of 8 alphanumeric digits divided equally into four letters and numbers as shown in Figure 5.18.

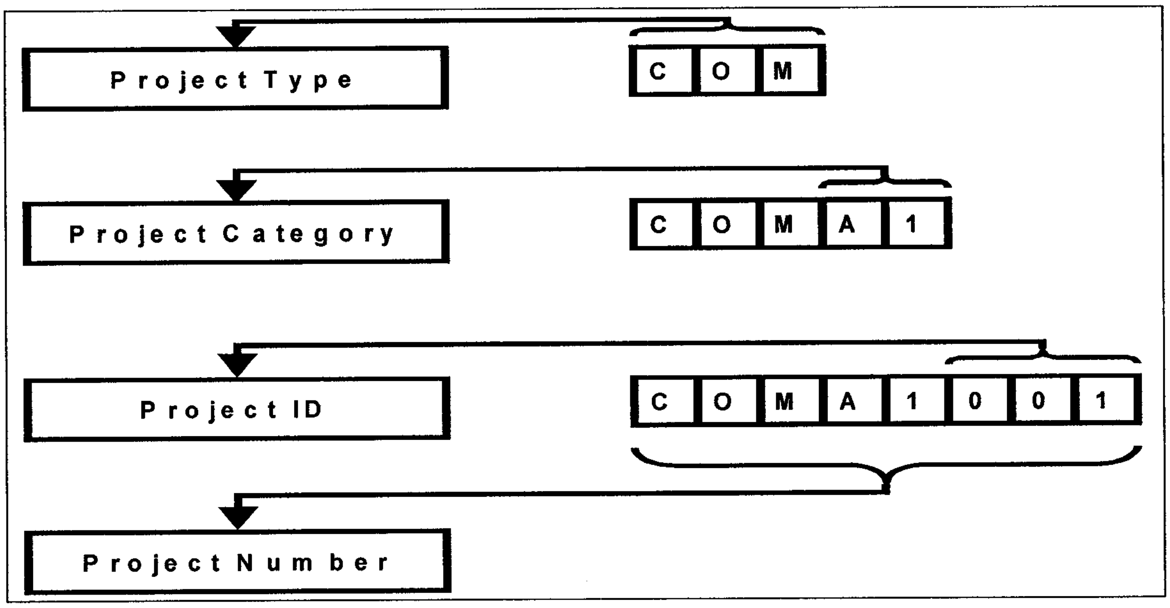


Figure 5.18 Numbering System for Parametric Database

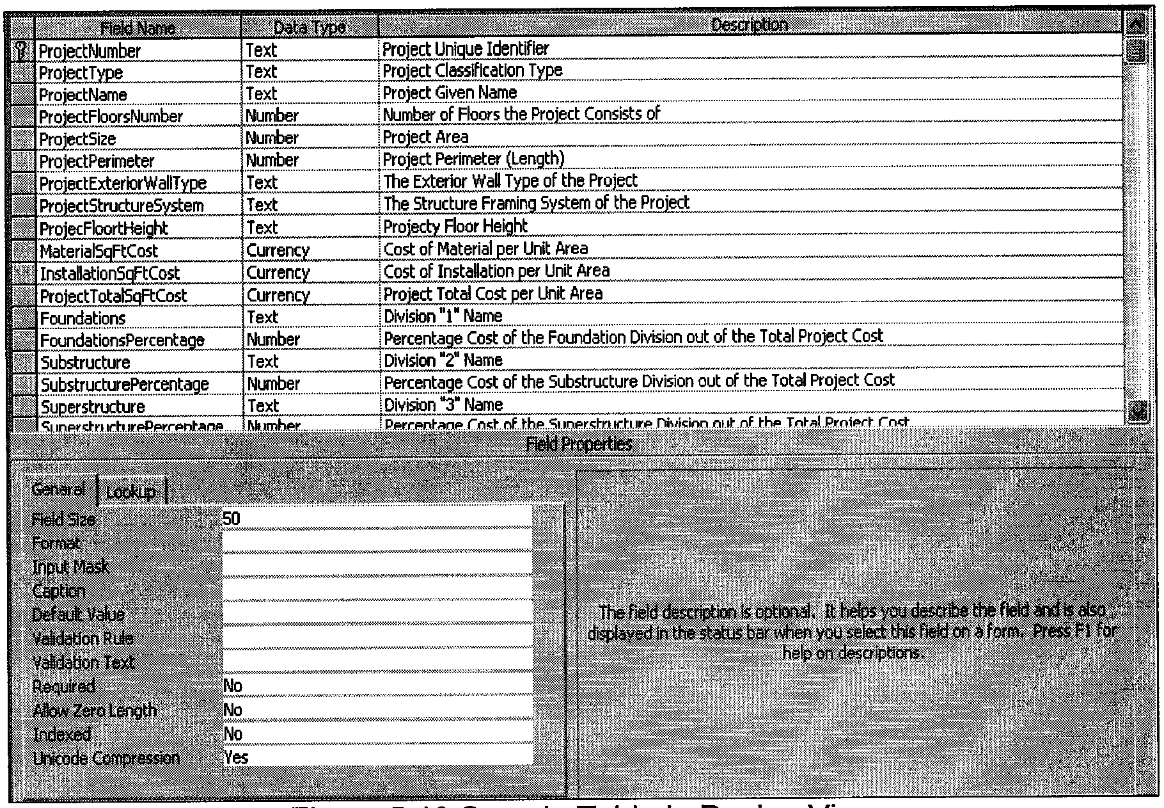
b) Step Two

Subsequent to setting up the numbering system to be used in this database, each project is assigned a unique identifier depending on its size, exterior wall and framing type. In this case the project number is the identifier, which links each project with its associated elements. Accordingly, tables' creation starts by distinguishing each field name, type and size as shown in Table 5.3, whereas Figure 5.19 exemplifies the table in design view. Afterwards, data entry progresses successively in the assigned tables, Figure 5.20 illustrates sample of these tables.

Table 5.3 Samples of Table's Fields Name, Type, and Size

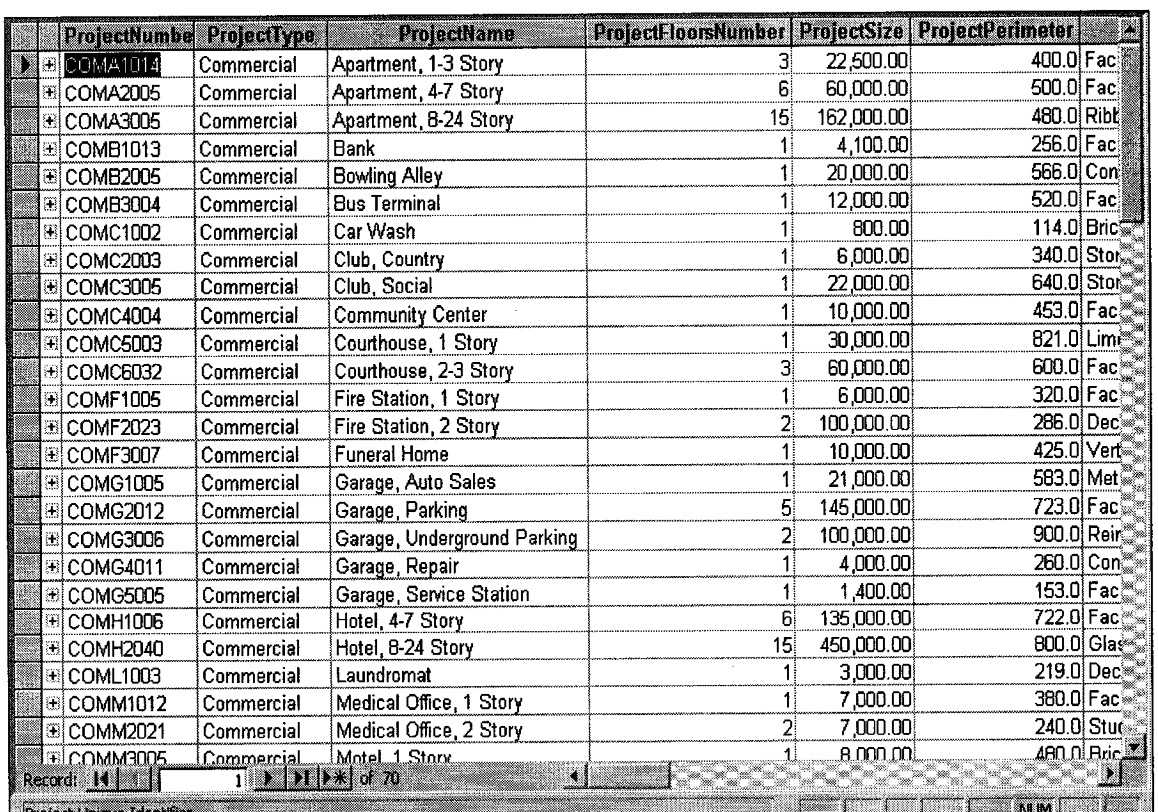
Field Name	Field Type	Field Size
Project Number	Text	8
Project Type	Text	15
Project Name	Text	50
Project Floors Number	Number	Byte
Project Size	Number	Single
Project Perimeter	Number	Single
Project Exterior Wall Type	Text	60
Project Structure System	Text	50
Project's Floor Height	Text	5
Project Material Cost per Unit Area	Currency	Currency
Project Installation Cost per Unit Area	Currency	Currency
Project Total Cost per Unit Area	Currency	Currency
Division "1" Name	Text	50
Foundations Division Percentage Cost	Number	Single
Division "2" Name	Text	50
Substructure Division Percentage Cost	Number	Single
Division "3" Name	Text	50
Superstructure Division Percentage Cost	Number	Single
Division "4" Name	Text	50
Exterior Closure Division Percentage Cost	Number	Single
Division "5" Name	Text	50
Roofing Division Percentage Cost	Number	Single
Division "6" Name	Text	50
Interior Construction Division Percentage	Number	Single
Division "7" Name	Text	50
Conveying Systems Division Percentage	Number	Single
Division "8" Name	Text	50
Mechanical Division Percentage Cost	Number	Single
Division "9" Name	Text	50
Electrical Division Percentage Cost	Number	Single
Division "11" Name	Text	50
Special Construction Division Percentage	Number	Single

All these tables are linked together through their primary and secondary or indexed keys as shown in Figure 5.21, while Figure 5.22 demonstrates a physical sample table.



Field Name	Data Type	Description
ProjectNumber	Text	Project Unique Identifier
ProjectType	Text	Project Classification Type
ProjectName	Text	Project Given Name
ProjectFloorsNumber	Number	Number of Floors the Project Consists of
ProjectSize	Number	Project Area
ProjectPerimeter	Number	Project Perimeter (Length)
ProjectExteriorWallType	Text	The Exterior Wall Type of the Project
ProjectStructureSystem	Text	The Structure Framing System of the Project
ProjecFloortHeight	Text	Projecty Floor Height
MaterialSqFtCost	Currency	Cost of Material per Unit Area
InstallationSqFtCost	Currency	Cost of Installation per Unit Area
ProjectTotalSqFtCost	Currency	Project Total Cost per Unit Area
Foundations	Text	Division "1" Name
FoundationsPercentage	Number	Percentage Cost of the Foundation Division out of the Total Project Cost
Substructure	Text	Division "2" Name
SubstructurePercentage	Number	Percentage Cost of the Substructure Division out of the Total Project Cost
Superstructure	Text	Division "3" Name
SuperstructurePercentage	Number	Percentage Cost of the Superstructure Division out of the Total Project Cost

Figure 5.19 Sample Table in Design View



ProjectNumbe	ProjectType	ProjectName	ProjectFloorsNumber	ProjectSize	ProjectPerimeter	
COMA1014	Commercial	Apartment, 1-3 Story	3	22,500.00	400.0	Fac
COMA2005	Commercial	Apartment, 4-7 Story	6	60,000.00	500.0	Fac
COMA3005	Commercial	Apartment, 8-24 Story	15	162,000.00	480.0	Ribt
COMB1013	Commercial	Bank	1	4,100.00	256.0	Fac
COMB2005	Commercial	Bowling Alley	1	20,000.00	566.0	Con
COMB3004	Commercial	Bus Terminal	1	12,000.00	520.0	Fac
COMC1002	Commercial	Car Wash	1	800.00	114.0	Bric
COMC2003	Commercial	Club, Country	1	6,000.00	340.0	Stor
COMC3005	Commercial	Club, Social	1	22,000.00	640.0	Stor
COMC4004	Commercial	Community Center	1	10,000.00	453.0	Fac
COMC5003	Commercial	Courthouse, 1 Story	1	30,000.00	821.0	Lim
COMC6032	Commercial	Courthouse, 2-3 Story	3	60,000.00	600.0	Fac
COMF1005	Commercial	Fire Station, 1 Story	1	6,000.00	320.0	Fac
COMF2023	Commercial	Fire Station, 2 Story	2	100,000.00	286.0	Dec
COMF3007	Commercial	Funeral Home	1	10,000.00	425.0	Vert
COMG1005	Commercial	Garage, Auto Sales	1	21,000.00	583.0	Met
COMG2012	Commercial	Garage, Parking	5	145,000.00	723.0	Fac
COMG3006	Commercial	Garage, Underground Parking	2	100,000.00	900.0	Reir
COMG4011	Commercial	Garage, Repair	1	4,000.00	260.0	Con
COMG5005	Commercial	Garage, Service Station	1	1,400.00	153.0	Fac
COMH1006	Commercial	Hotel, 4-7 Story	6	135,000.00	722.0	Fac
COMH2040	Commercial	Hotel, 8-24 Story	15	450,000.00	800.0	Glas
COML1003	Commercial	Laundromat	1	3,000.00	219.0	Dec
COMM1012	Commercial	Medical Office, 1 Story	1	7,000.00	380.0	Fac
COMM2021	Commercial	Medical Office, 2 Story	2	7,000.00	240.0	Stuc
COMM3005	Commercial	Motel, 1 Story	1	8,000.00	480.0	Bric

Figure 5.20 Sample Table After Data Entry

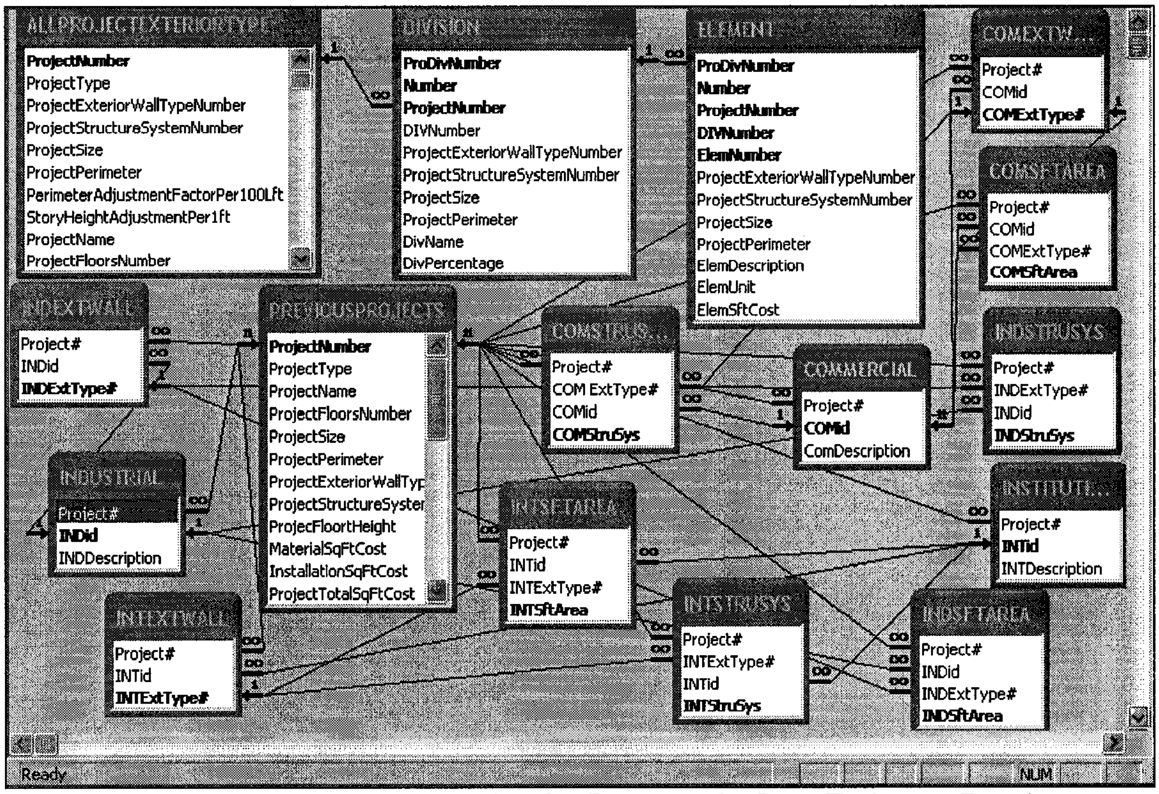


Figure 5.21 Tables Relationships for Parametric Cost Estimate Database

ProjectNumbe	ProjectType	ProjectName	ProjectFloorsNumber	ProjectSize	ProjectPerimeter	
COMA1014	Commercial	Apartment, 1-3 Story	3	22,500.00	400.0	Fac

ProjectType	Project	ProjectS	ProjectSize	Projec	Perimete	StoryHeightAdjustmentPer1ft	ProjectNan
COMMERCIAL	1	2	22,500.00	400.0	$4.68	$1.68	Apartment, 1-3 St

ProDivNumbe	Number	DIVNu	ElemNuml	ProjectExt	Projec	ProjectSiz	ProjectPerim	ElemD
131	14	1.0	1.1	1	2	22,500.00	400.0	Footings and
131	14	1.0	1.9	1	2	22,500.00	400.0	Excavation a
132	14	2.0	2.1	1	2	22,500.00	400.0	Slab on Grad
133	14	3.0	3.1	1	2	22,500.00	400.0	Columns, Be
133	14	3.0	3.5	1	2	22,500.00	400.0	Elevated Floo
133	14	3.0	3.7	1	2	22,500.00	400.0	Roof
133	14	3.0	3.9	1	2	22,500.00	400.0	Stairs
134	14	4.0	4.1	1	2	22,500.00	400.0	Walls
134	14	4.0	4.6	1	2	22,500.00	400.0	Doors
134	14	4.0	4.7	1	2	22,500.00	400.0	Windows and
135	14	5.0	5.1	1	2	22,500.00	400.0	Roof Covering
135	14	5.0	5.7	1	2	22,500.00	400.0	Insulation
136	14	6.0	6.1	1	2	22,500.00	400.0	Partitions
136	14	6.0	6.4	1	2	22,500.00	400.0	Interior Doors
136	14	6.0	6.5	1	2	22,500.00	400.0	Wall Finishes
136	14	6.0	6.6	1	2	22,500.00	400.0	Floor Finishe
136	14	6.0	6.7	1	2	22,500.00	400.0	Ceiling Finish
136	14	6.0	6.9	1	2	22,500.00	400.0	Interior Surfac
137	14	7.0	7.1	1	2	22,500.00	400.0	Elevators
138	14	8.0	8.1	1	2	22,500.00	400.0	Plumbing

Record: 1 of 27

Datasheet View NUM

Figure 5.22 Physical Sample Table

Furthermore, blank tables are designed and made available for the global module to be used for writing data on new projects. Two tables linked to the AutoCAD database are created so that the floor's area, height, and building perimeter, which are read from the drawing, are incorporated in this database. These tables are named "Polyline" and "Perimeter" after the tables they are linked to. This minimizes the retrieving time of required data and accordingly accelerates necessary calculations.

c) Step Three

The interface that executes required calculations and allows user visualization is inherited in the global module that will be discussed in later paragraphs. The list of output reports shown in Figure 5.23 is given in chapter Six.

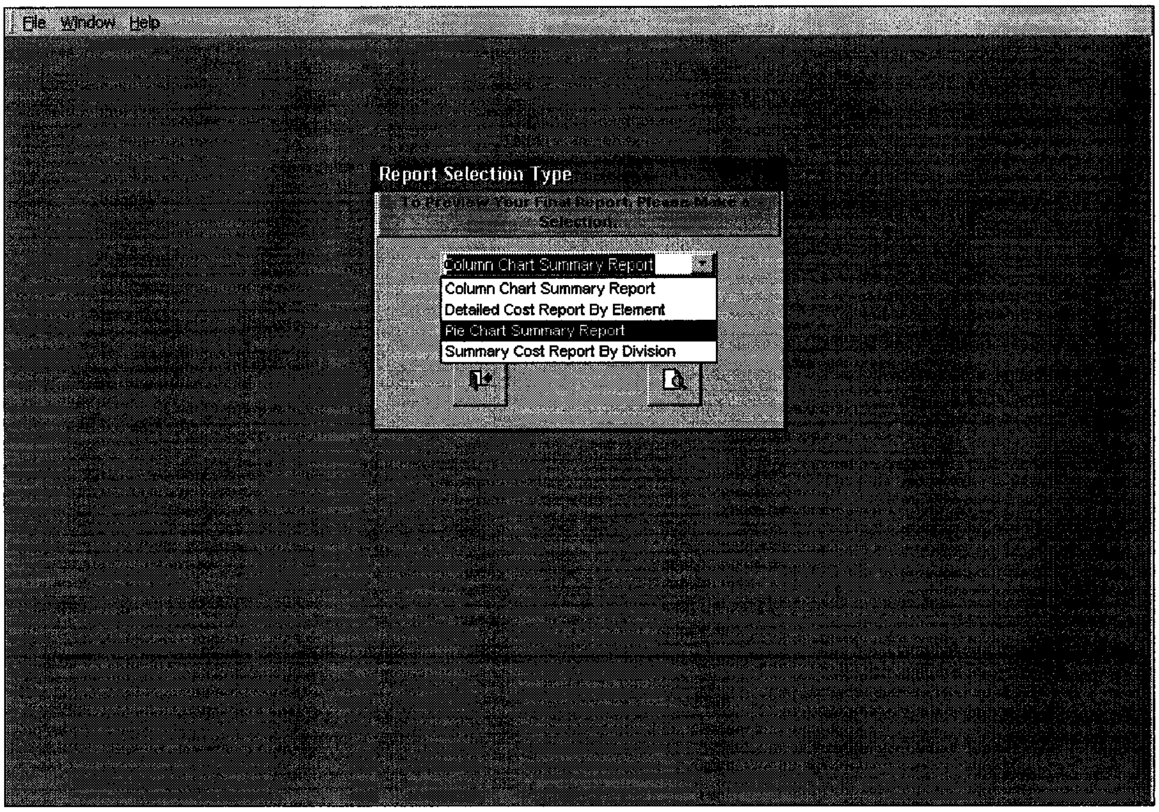


Figure 5.23 Output Reports Selection for Parametric Estimate

5.2.4 Life Cycle Costing Database

Series of blank tables are designed to store data that is used by the Life Cycle Analysis. This data includes rent, retail, and TOEFEL. It also stores information on new projects. Furthermore, two main tables are created; the first holds adjustment factors for income and expenses while the second incorporates the percentage of the expenses item breakdown based on BOMA publications data. These factors depend on the city, location, building height (number of floors), size (area), and age. Accordingly, the following three steps are considered:

a) Step One

Tables field's name, type and size have to be identified, as seen in Tables 5.4 to 5.7 for the rent, retail, TOEFEL, adjustment factors and other tables respectively.

Table 5.4 Forecasted Rent Table's Fields Name, Type, and Size

Field Name	Field Type	Field Size
n	Number	Integer
Rent Value	Number	Single
Year	Number	Single
Future Year	Text	Single

Table 5.5 Forecasted Retail Table's Fields Name, Type, and Size

Field Name	Field Type	Field Size
n	Number	Integer
Retail Value	Number	Single
Year	Number	Single
Future Year	Text	Single

Table 5.6 Forecasted Expenses Table's Fields Name, Type, and Size

Field Name	Field Type	Field Size
n	Number	Integer
Expenses Value	Number	Single
Year	Number	Single
Future Year	Text	Single

Table 5.7 Adjustment Factors Table's Fields Name, Type, and Size

Field Name	Field Type	Field Size
City Number	Text	Byte
City Name	Text	50
Size	Text	50
Number of Floors	Text	50
ICF	Number	Single
ILF	Number	Single
ISF	Number	Single
IAF	Number	Single
IHF	Number	Single
ECF	Number	Single
ELF	Number	Single
ESF	Number	Single
EAF	Number	Single
EHF	Number	Single

b) Step Two

Once all the required tables' fields are identified, sets of queries holding expressions and equations are designed and implemented to execute necessary calculations. Table 5.8 lists sample of these expressions used in these queries.

Table 5.8 Sample of the Expressions Used in the Designed Queries

Clean: ([CleanValuePerSft])*([SumOfTotalExpensesPresentValue]/[ProjectTotalArea])
Repair: ([RepairValuePerSft])*([SumOfTotalExpensesPresentValue]/[ProjectTotalArea])
Utilities: ([UtilitiesValuePerSft])*([SumOfTotalExpensesPresentValue]/[ProjectTotalArea])
Administration: ([AdministrationValuePerSft])*([SumOfTotalExpensesPresentValue]/[ProjectTotalArea])
Fixed: ([FixedValuePerSft])*([SumOfTotalExpensesPresentValue]/[ProjectTotalArea])
Leasing: ([LeasingValuePerSft])*([SumOfTotalExpensesPresentValue]/[ProjectTotalArea])
ExpensePerYear: [Expense Rate]*[AverageFloorArea]
TotalNetPresentValue: [Income PV]-[TOEFEL PV]+[Salvage PV]-[Total Capital Cost]
NetOperatingIncomePerYear: [TotalIncomePerYear]-[ExpensePerYear]
SIR: ([Total Income PV]+[Salvage PV])/([Total Capital Costs]+[Total Expenses PV])
TotalIncomePresentValue: [TotalIncomePerYear]*((1+[InterestRate]/100)^(-[n]))

These queries are the data source for sets of pre-designed sub-forms, which are inherited into list of output reports.

c) Step Three

The LCC module supplies the user with list of reports to choose from as illustrated in Figure 5.24. Each of those output reports is better illustrated through the case study in chapter six.

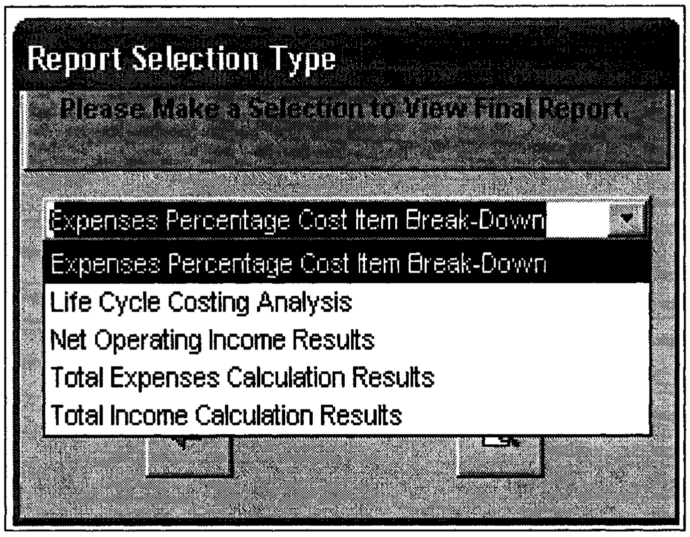


Figure 5.24 List of Provided Output Reports for LCC

5.2.5 Sensitivity Analysis Database

In this database, list of blank tables are designed and developed for the LCC module to store the forecasted cost and income values, user inputted data and range of deviation besides the project information. Moreover, a series of different types of queries (Select, Append and Delete) are designed containing expressions and equations to accomplish all needed calculations for the sensitivity analysis method. Table 5.9 shows samples of the inherited expressions in the queries, which are used to calculate the Net Present Value (NPV) of each parameter based on the range of deviation of these values.

Table 5.9 Sample of the Expressions Used in the Designed Queries for NPV

NPVonCapitalVariation: ([sumofsalvagepresentvalue]+[sumofrentpresentvalue]+[sumofretailpresentvalue] +[sumofotherincomepresentvalue])-([capitalpresentvalue]+[sumoftotalexpensespresentvalue]))
Factor: (1+([ErrorsRange]))
RetailPresentValue: ([SumOfRetailPresentValue]*[Factor])
FutureYear: ([CurrentYear]+[LCCPeriodOfStudy])
SalvagePresentValue: [SalvageValue]*(1+[InterestRate]/100)^(-[LCCPeriodOfStudy])
TOEFEL PV: ([TOEFEL / YEAR]*(1+[INTERESTRATE]/100)^(-[YEAR]))
Total Net Present Value: ([Total Income PV]+[Salvage PV]-[Total Capital Costs]-[Total Expenses PV])

The user is provided with set of predefined lists of parameters to choose from as shown in Figure 5.25.

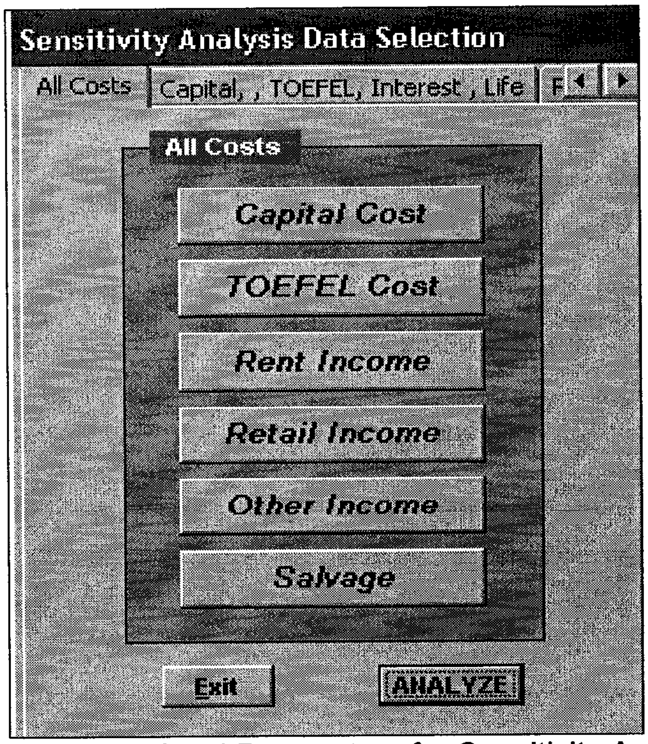


Figure 5.25 Set of Predefined Parameters for Sensitivity Analysis Method

As soon as the user clicks the “Analyze” button, the interface calculates the NPV of all the chosen parameters based on the range of deviation that has been entered. Once these NPV’s are computed the interface sends them in a tabulated format to spreadsheet (MS Excel) to draw the sensitivity analysis graph. For this reason, MS Excel has been customized to fit the requirements of implementing these tasks as well as the requirement of designing internal modules to ease the process of drawing the graph. A better example of these issues is provided in chapter six.

5.3 AutoCAD Module's Development (Phase 2)

Following the implementation of all needed databases and of the preliminary estimate module, the development procedures of this module are started. As mentioned earlier in Chapter Four, AutoCAD built-in Visual Basic for Application (VBA) and Auto Lisp are employed in this process. The external database is connected to AutoCAD allowing the module to write the 3D drawing's parameters directly and instantly to it as demonstrated in Figures 5.26 and 5.27.

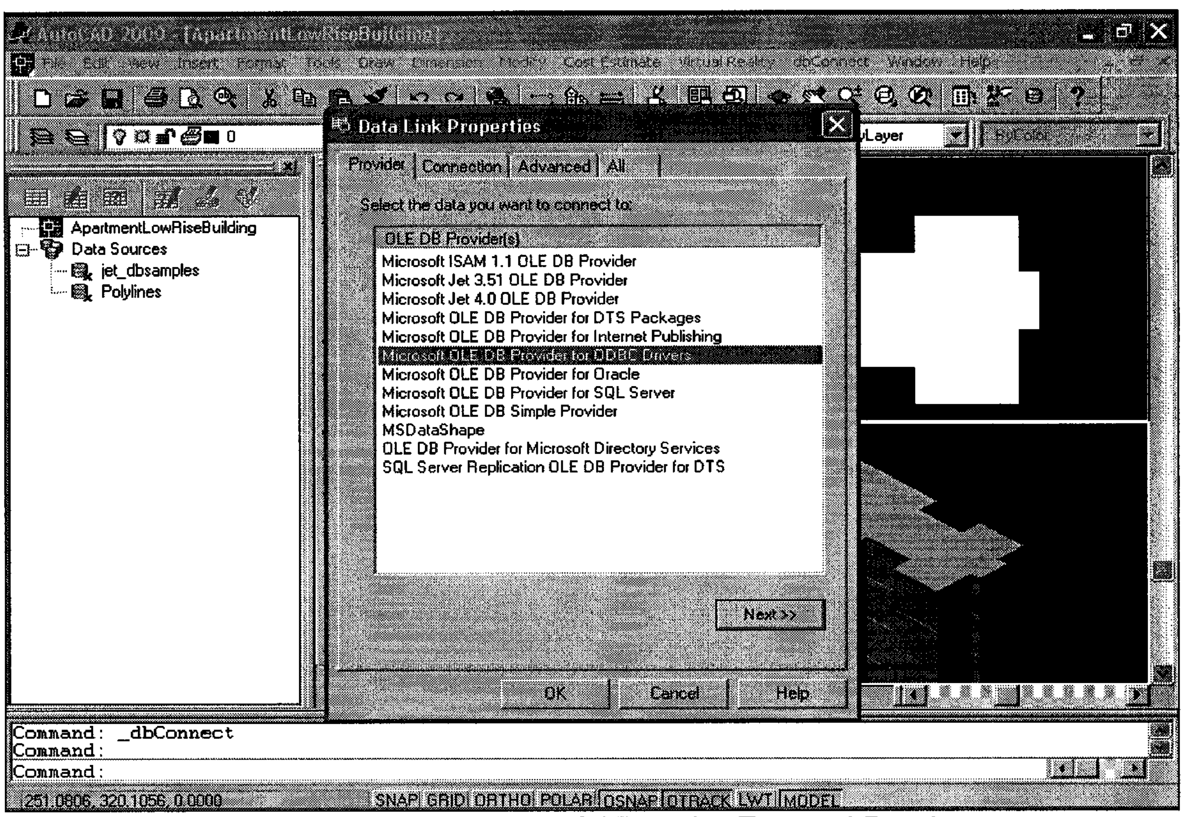


Figure 5.26 Connecting AutoCAD to the External Database

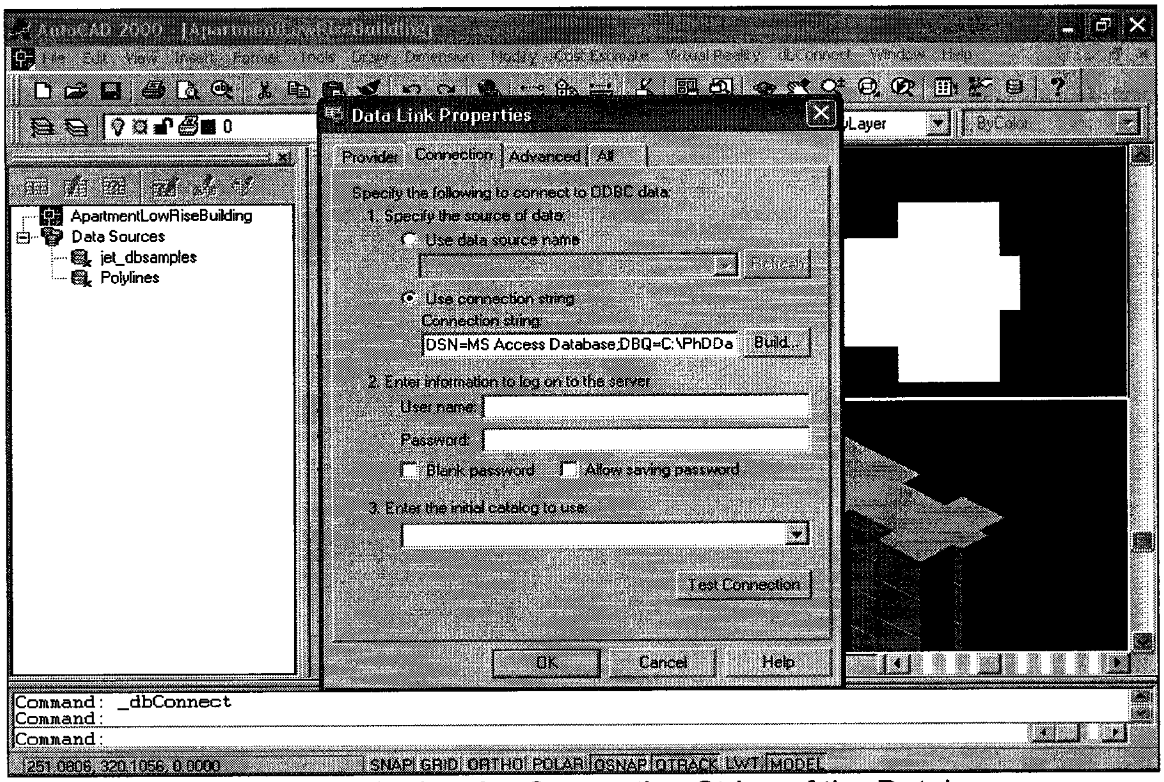


Figure 5.27 Assigning the Connection String of the Database

Once the connection is achieved, the module's development starts by declaring sets of variables (e.g. height, area, and perimeter), by identifying the path used to make instant connection and by carrying out essential tasks. For this reason, VBA coding lines are written to automate this process as shown in Figure 5.28. The module incorporates three class modules designed and implemented to perform the following tasks:

- The first read the area and height for each floor and write it to the external database.
- The second read the building perimeter and write it to the external database.
- The third provides the user with the floors area and their average instantly.

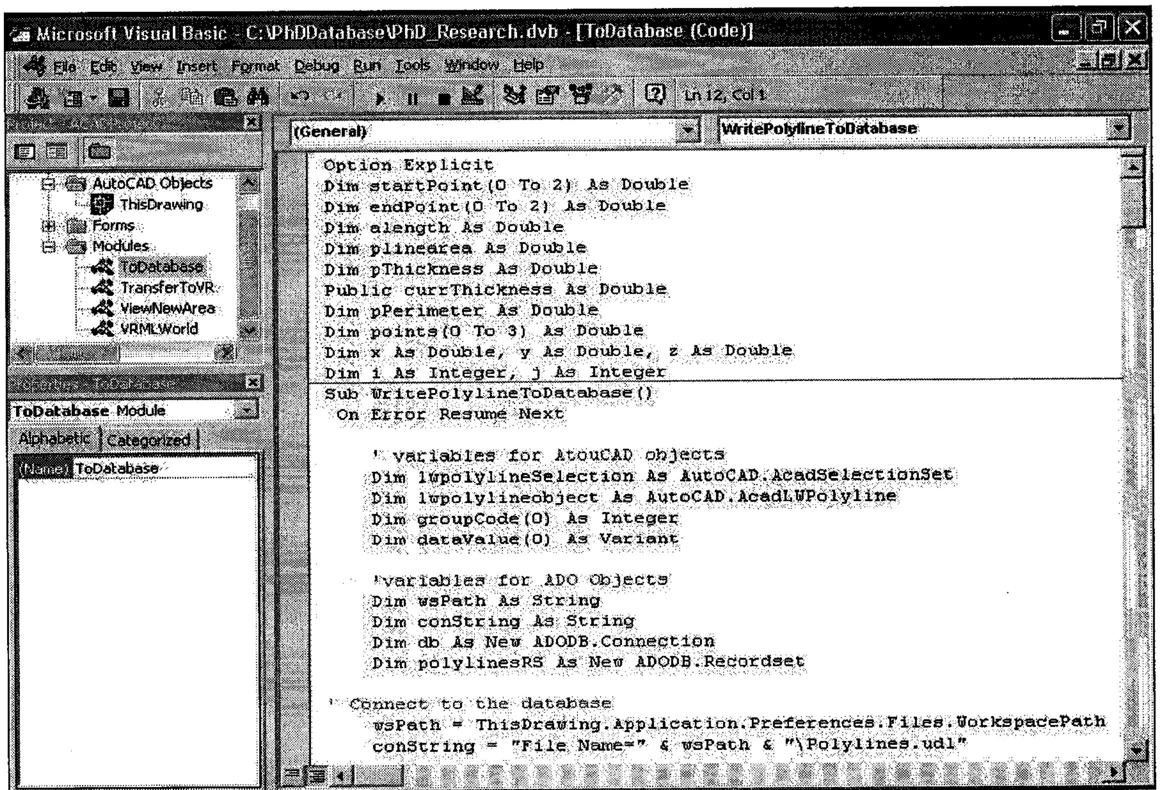


Figure 5.28 Sample of the Coding Lines Used in the AutoCAD Module

To simplify the application of these modules, AutoCAD main menu is customized in a way that the user quickly executes the needed action. This is accomplished by modifying Auto Lisp's executable files by adding sets of coding lines. Figures 5.29 through 5.32 demonstrate the preceding acts.

After the user modifies the 3D drawing as desired, this can be exported to 3D Studio for rendering and then be exported again to virtual reality for animation and visualization. The user is able to perform these exportations through the use of the customized drop down menu as shown in Figures 5.33 and 5.34.

Lists of 3D-CAD drawings were prepared for each project category and stored in a separate database so that the DSS uses them in selecting the closest drawing that has an area close to the forecasted one based on the user's budget.

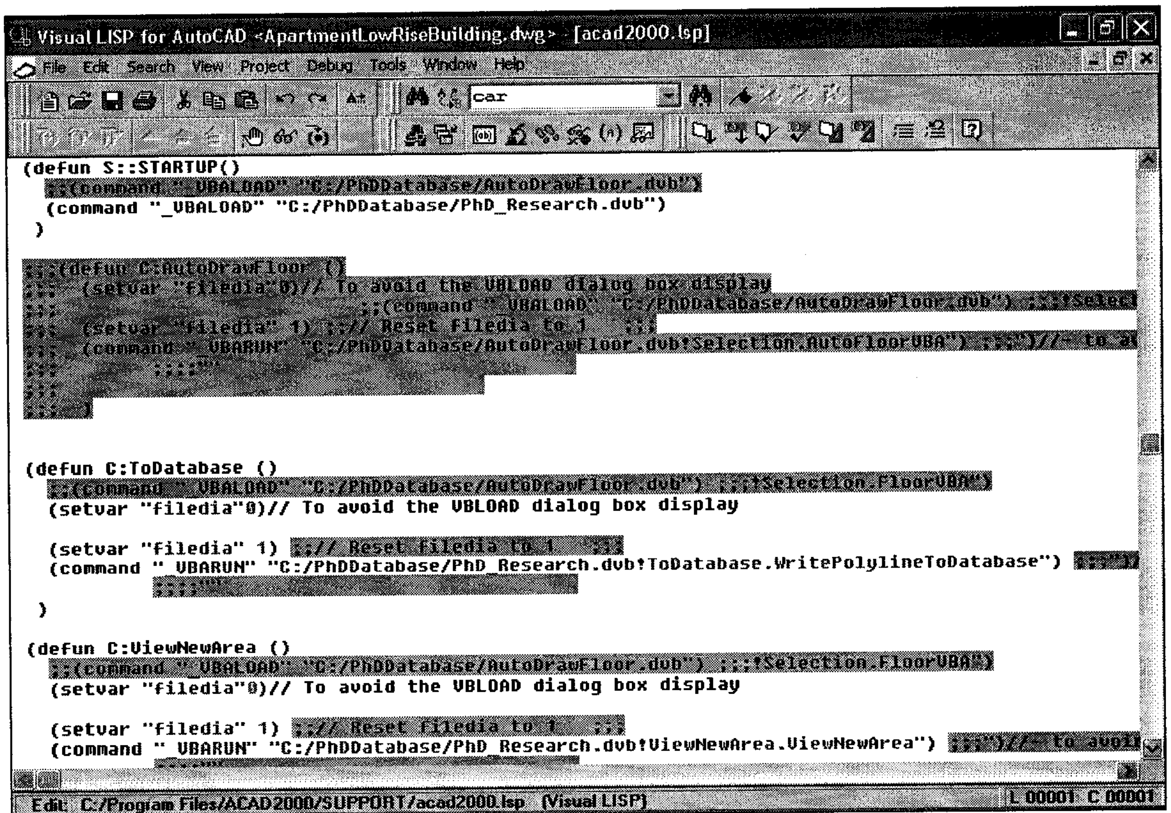


Figure 5.29 Adding New Coding Lines to Auto Lisp Executable Files

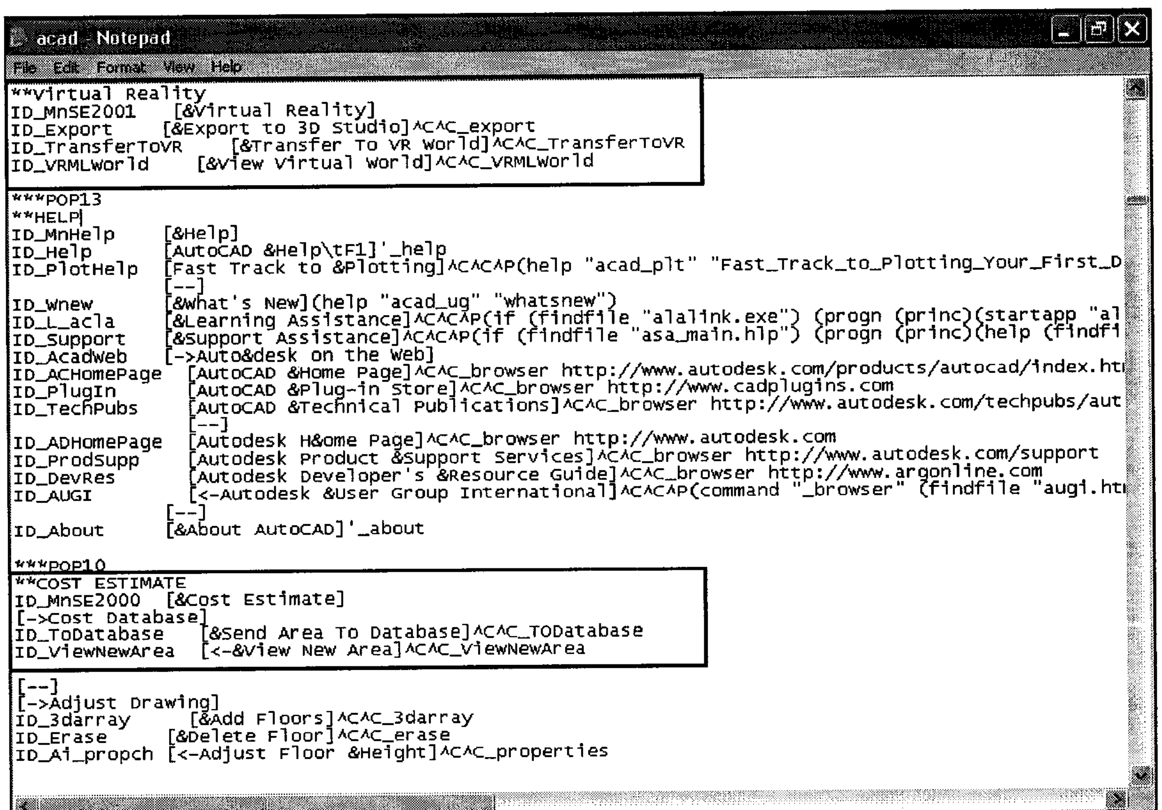


Figure 5.30 Adding New Coding Lines to AutoCAD Menu File

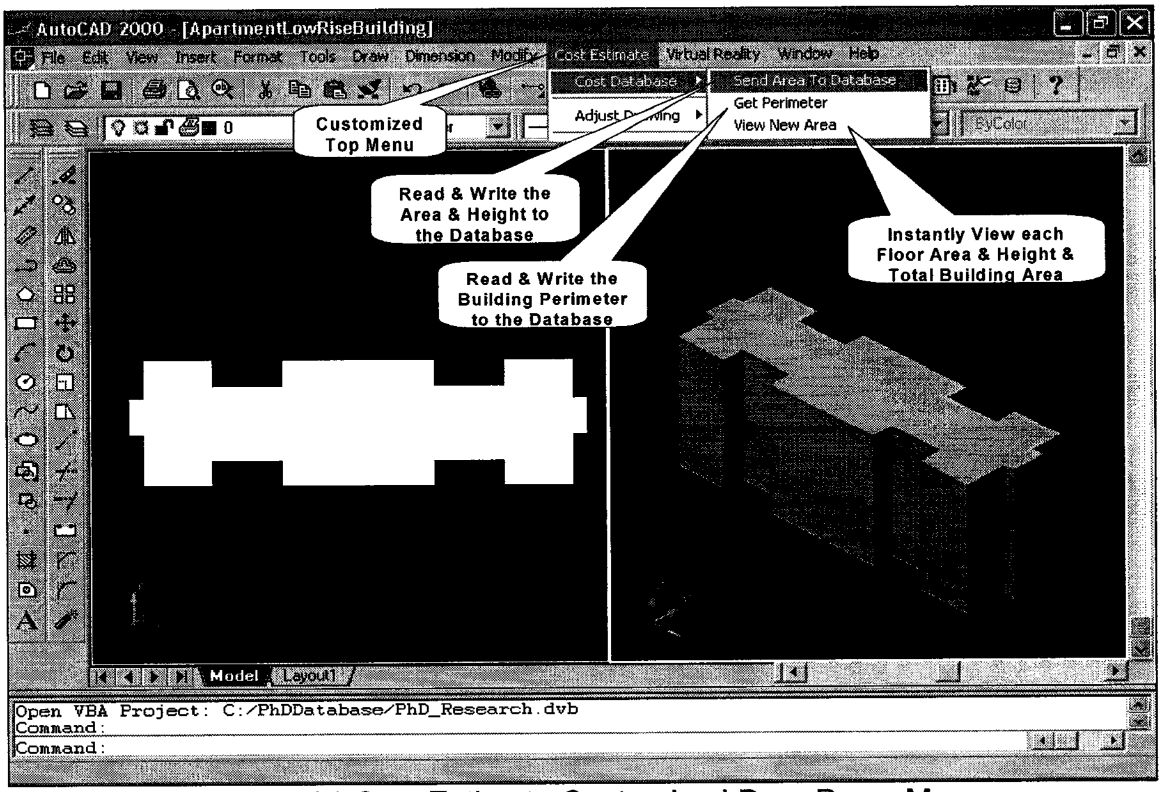


Figure 5.31 Cost Estimate Customized Drop Down Menu

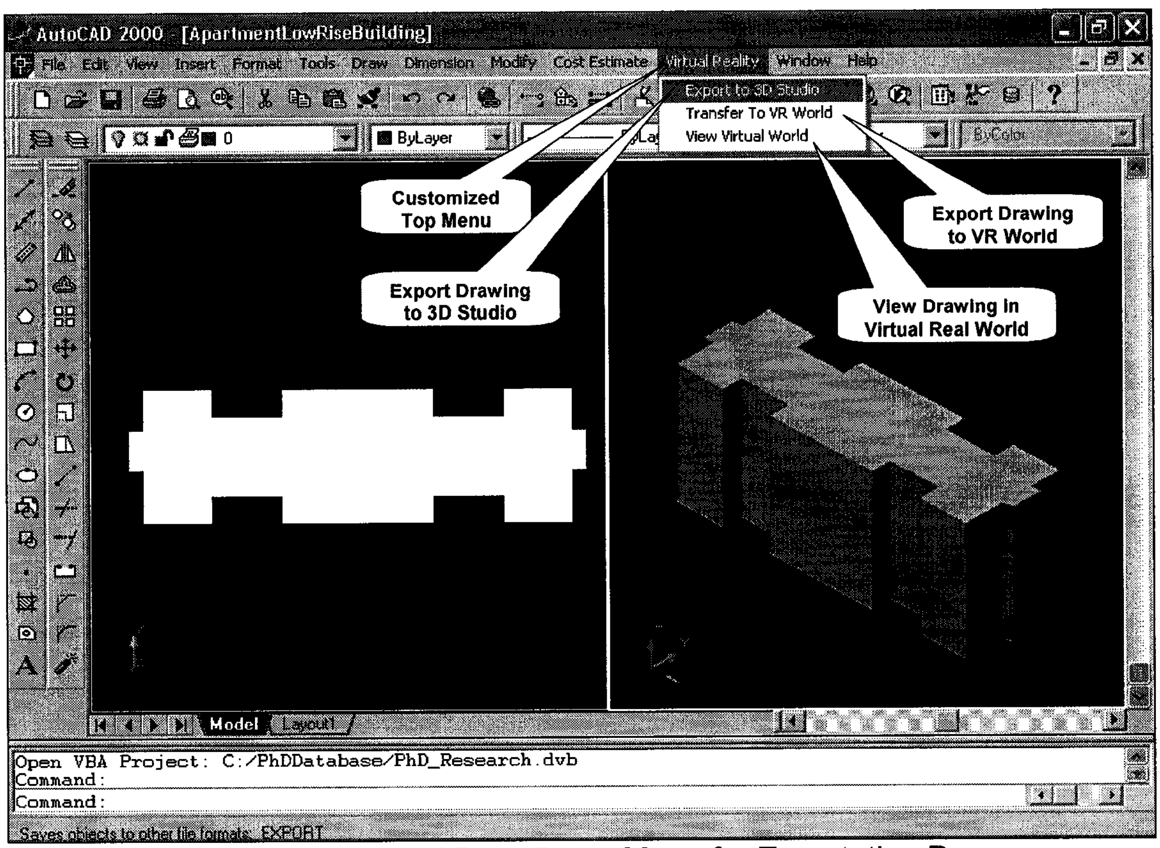


Figure 5.32 Customized Drop Down Menu for Exportation Purposes

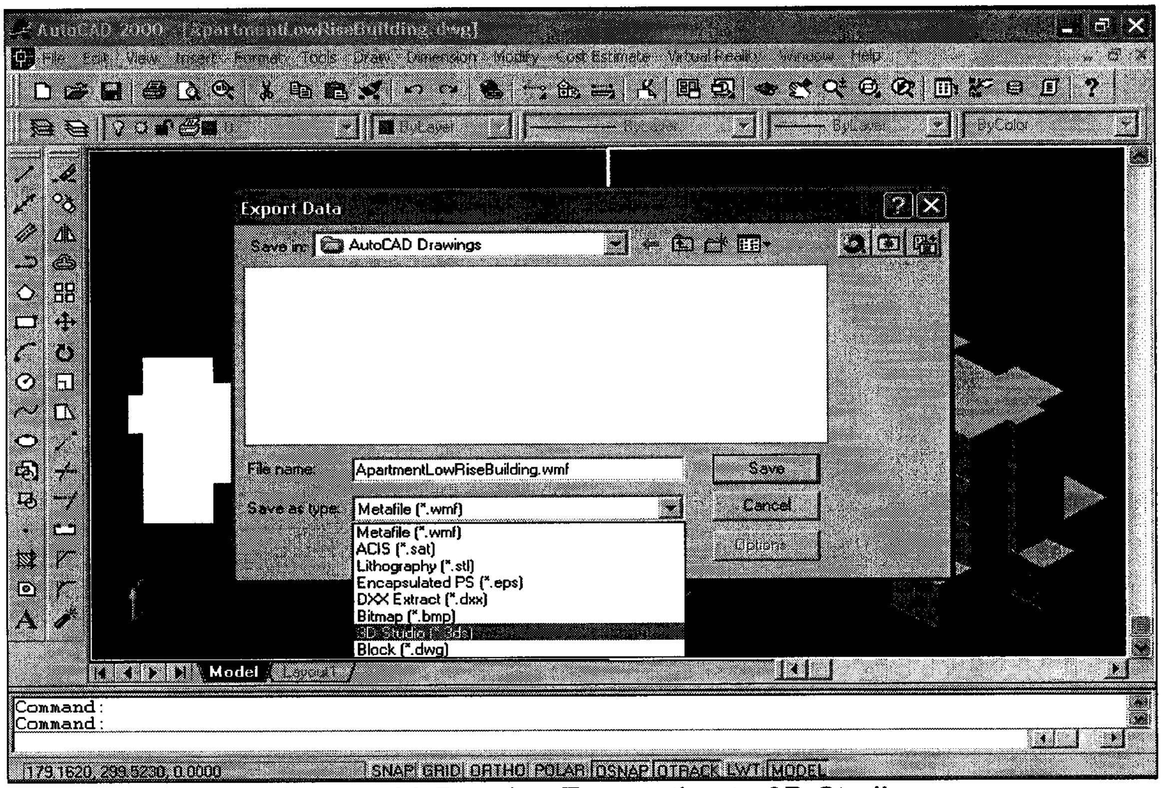


Figure 5.33 Drawing Exportation to 3D Studio

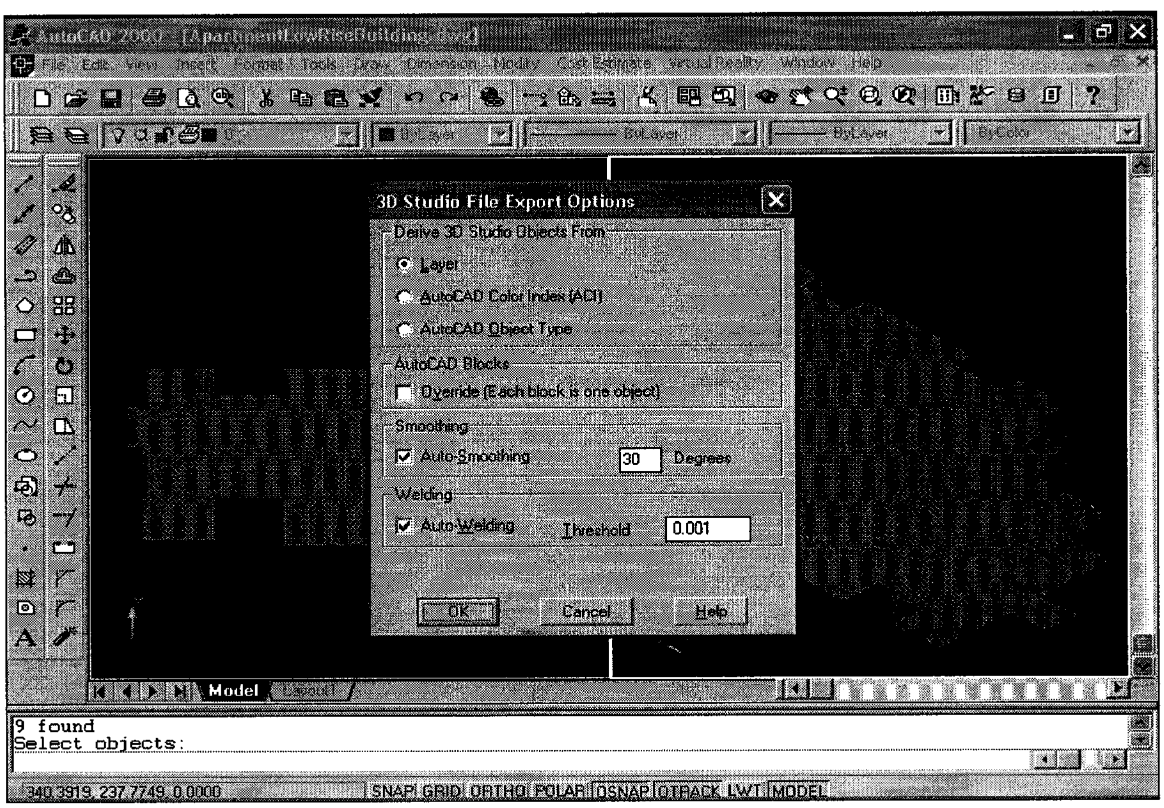


Figure 5.34 Setting the Exportation Options

For instance, for the Low Rise building category, a list of drawings that has an area range of 8,000 ft^2 and 36,000 ft^2 with a step of 300 ft^2. On the other hand, for the High Rise building category, a list of drawings was created having the area ranges from 95,000 ft^2 to 240,500 ft^2 with a difference of 1,500 ft^2. having done that, the implementation of this phase is fulfilled, and, accordingly, the next phase can be started.

5.4 Global VB Module's Development (Phase 3)

As discussed in Chapter Four, this module is the platform that manages the access to all other modules besides integrating the parametric estimate module and performing all necessary calculations. For these purposes, a number of forms are designed and implemented. At the start, a main form is shown where the user selects the desired type of estimate as illustrated in Figure 5.35.

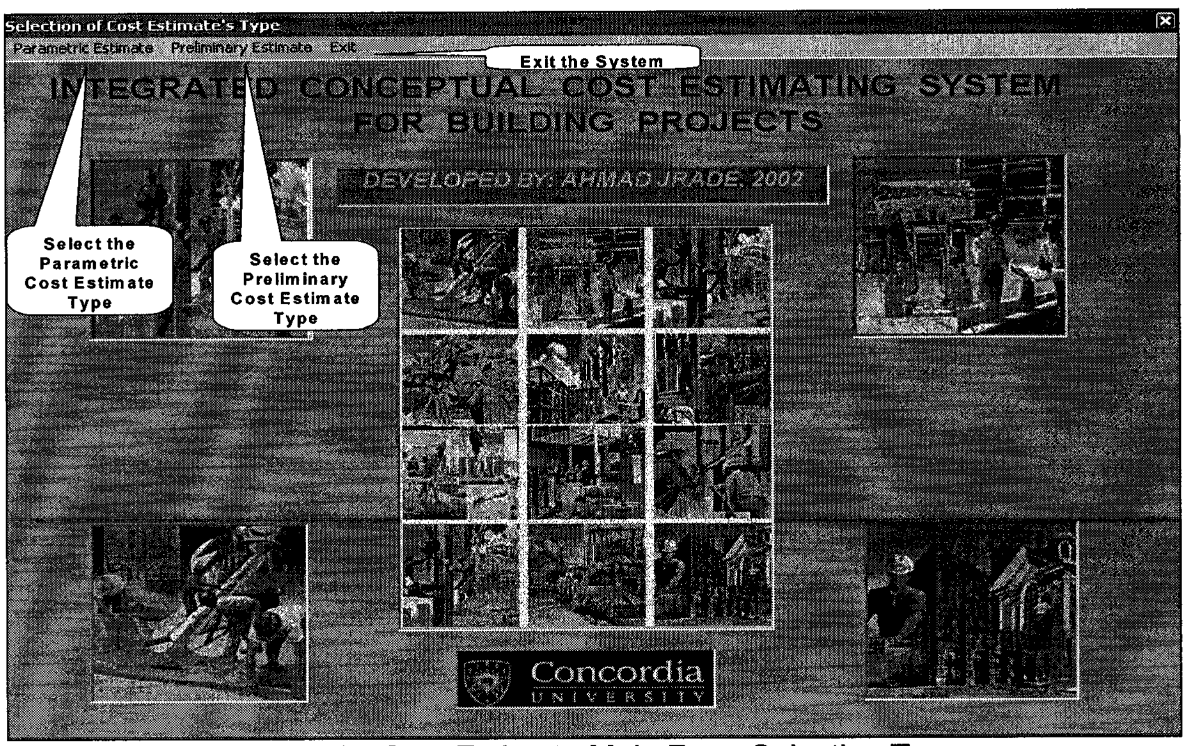


Figure 5.35 Cost Estimate Main Form Selection Type

In the case of selecting the Preliminary Estimate, from the same form, the user is able to select the WBS, Units, and Data Source type. Based on the selected combinations, the system connects to the required module and shows its associated form. If Assembly, Imperial, and Published Data are the preferred combinations as demonstrated in Figure 5.36, the system instantly communicates the Preliminary module and opens the form shown in Figure 5.37.

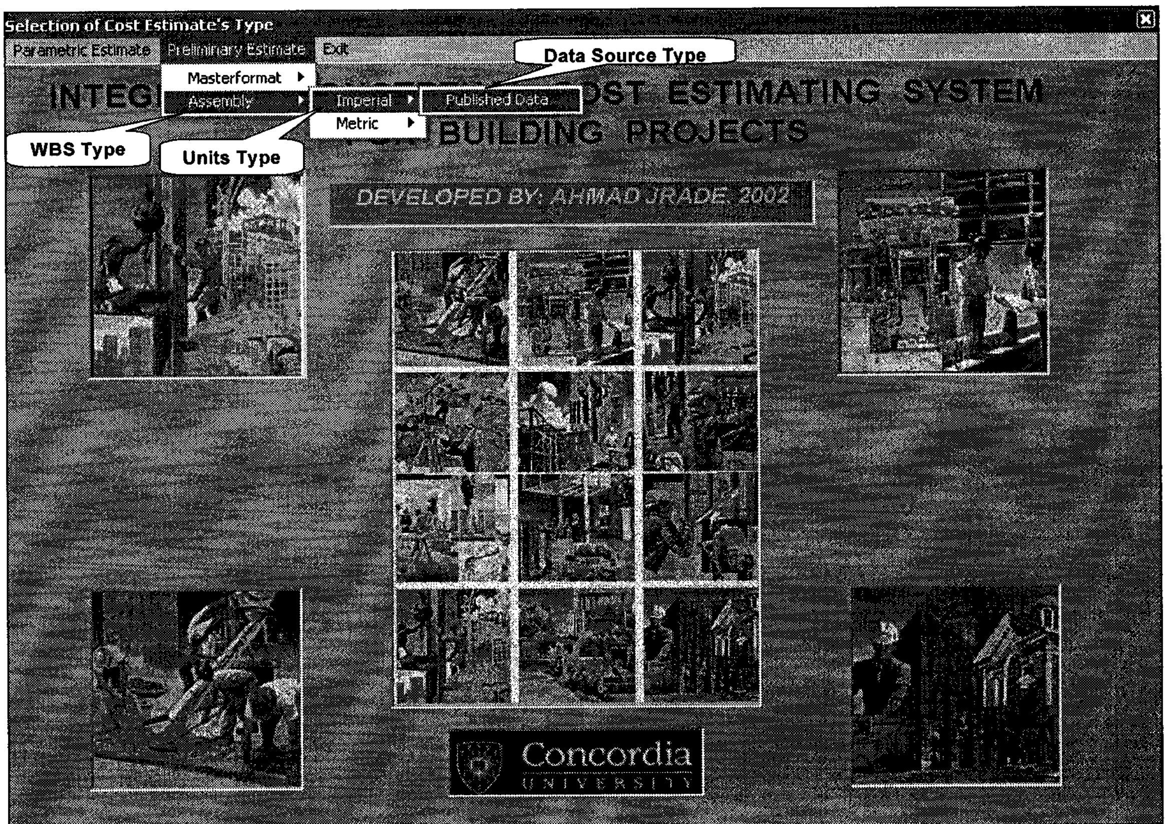


Figure 5.36 WBS, Units and Cost Data Source Selection

On the other hand, if Masterformat, Imperial and Published Data are the selected combination, then the system interconnects the Preliminary module and exhibits a form asking the user to input the project information as shown in Figure 5.38.

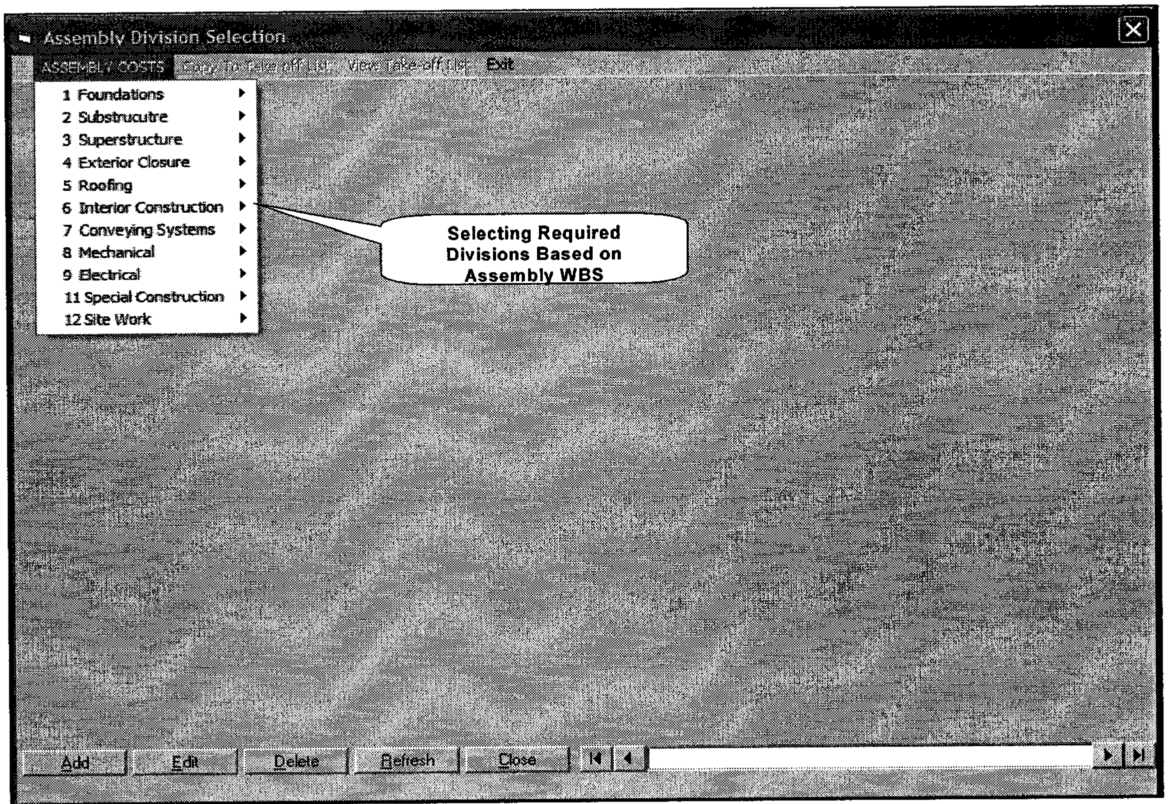


Figure 5.37 Selecting Required Divisions Based on Assembly WBS

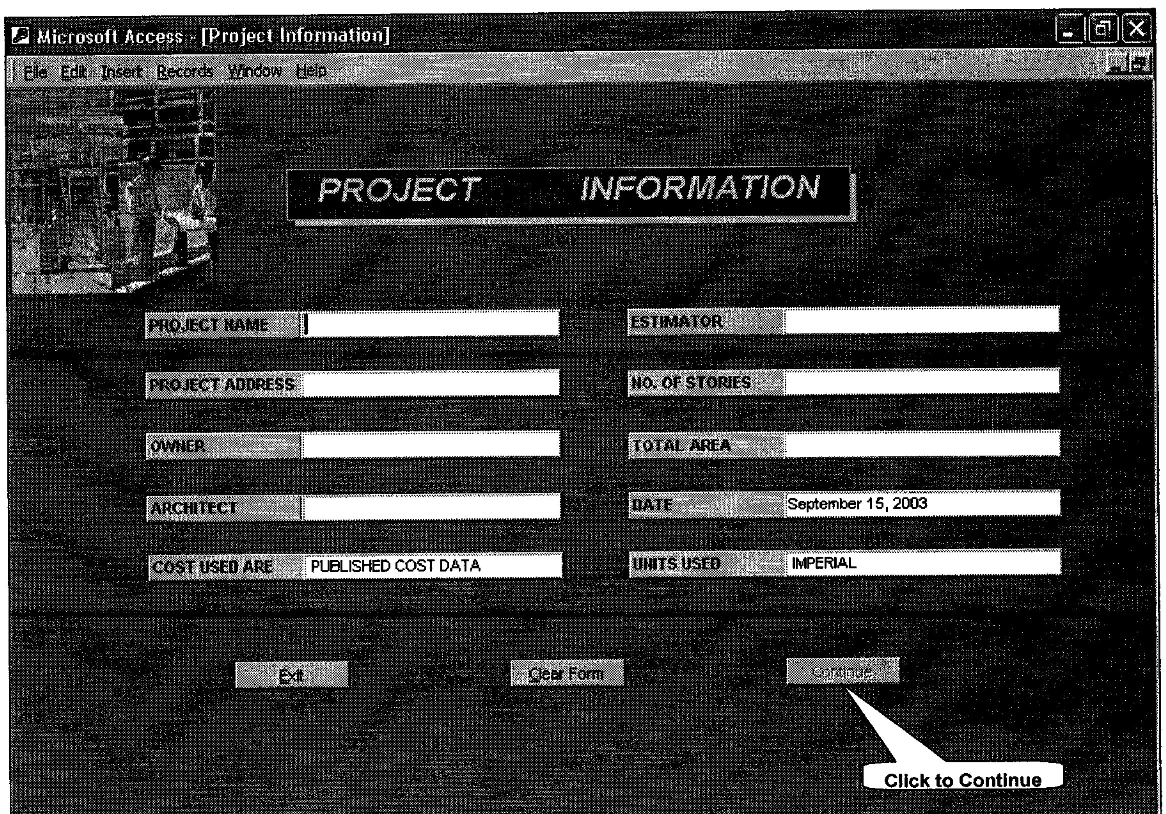


Figure 5.38 Project Information Input Form for Preliminary Estimate.

Once all needed information is keyed in and the "Continue" button is clicked, the module asks the user to select from the Eight Major Canadian Cities the desired one as shown in Figure 5.39.

Accordingly, the user starts the divisions' selection process and starts building up the take off list as explained previously in paragraph 5.2.1 Step Three.

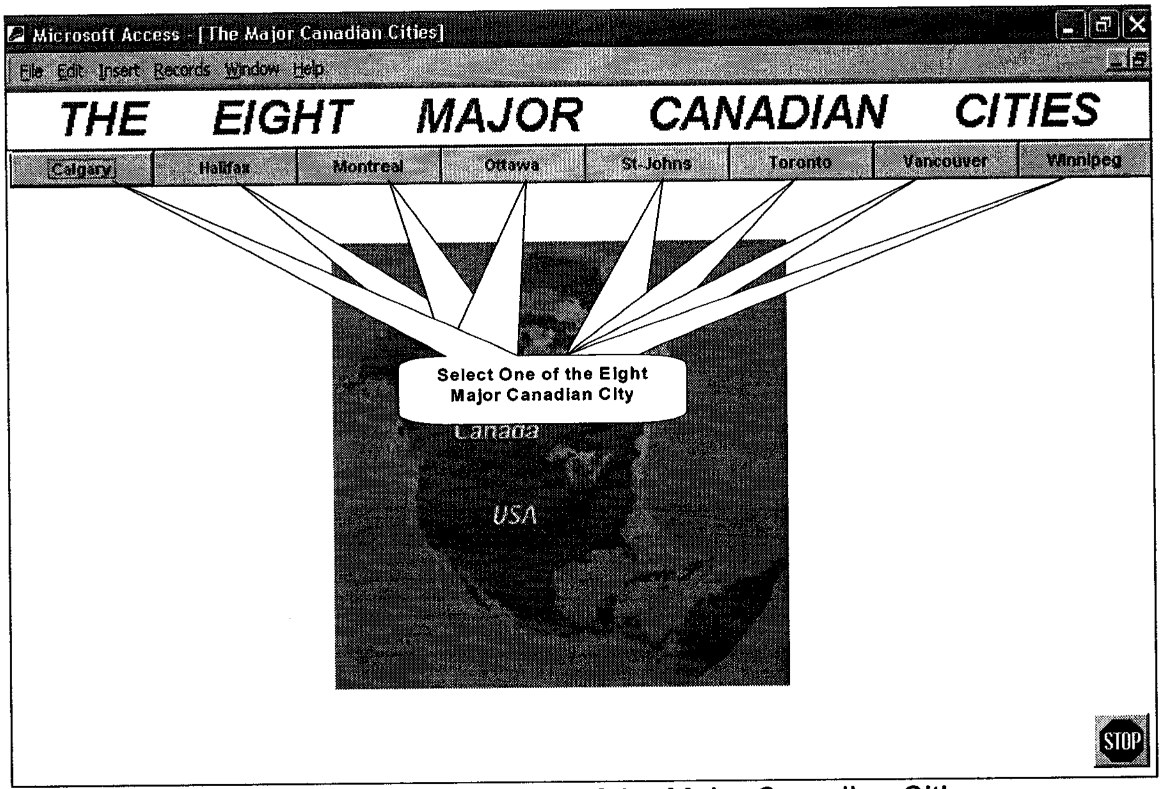


Figure 5.39 Selecting One of the Major Canadian Cities

For Parametric Estimate preference, the WBS, Units, and Cost Data Source types administer the selection's combinations. If Assembly, Imperial, and National Cost Data are the favored combinations, the system runs the associated module and consequently displays a form requesting the user to choose a project close to the proposed one from the three provided types "Commercial", "Industrial", and "Institutional", as exemplified in Figure 5.40.

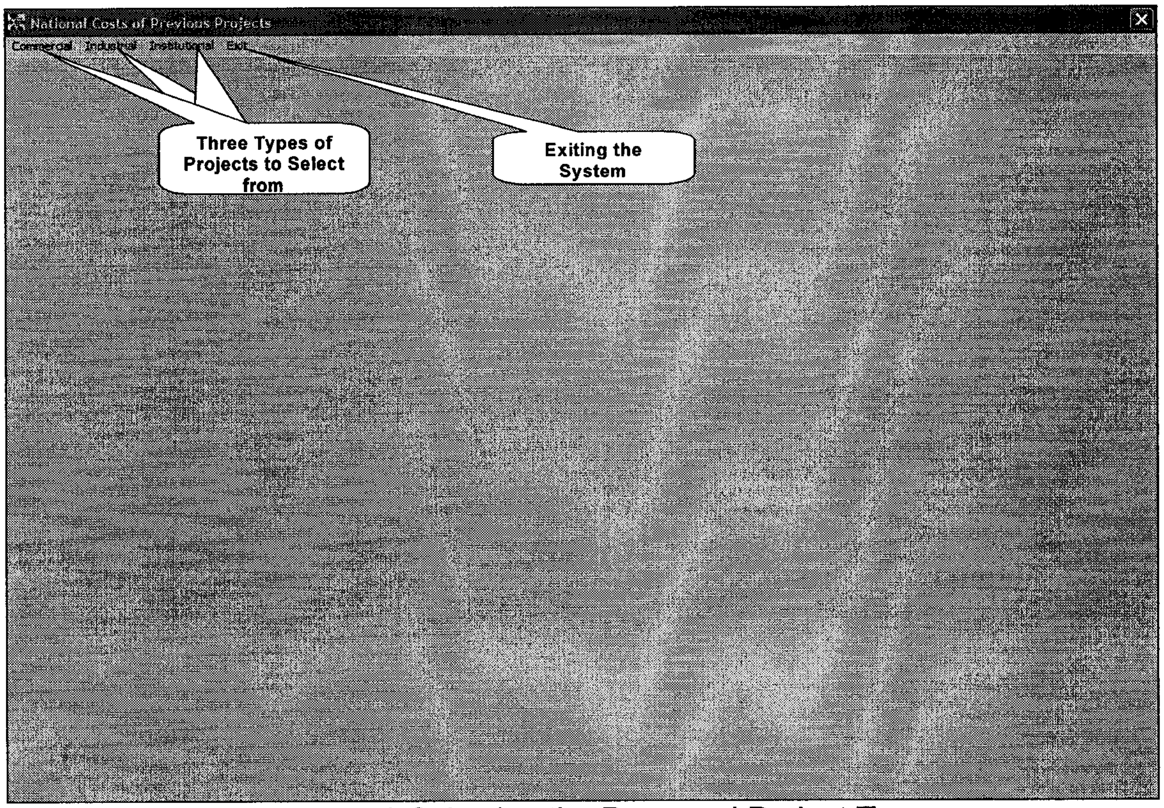


Figure 5.40 Selecting the Proposed Project Type

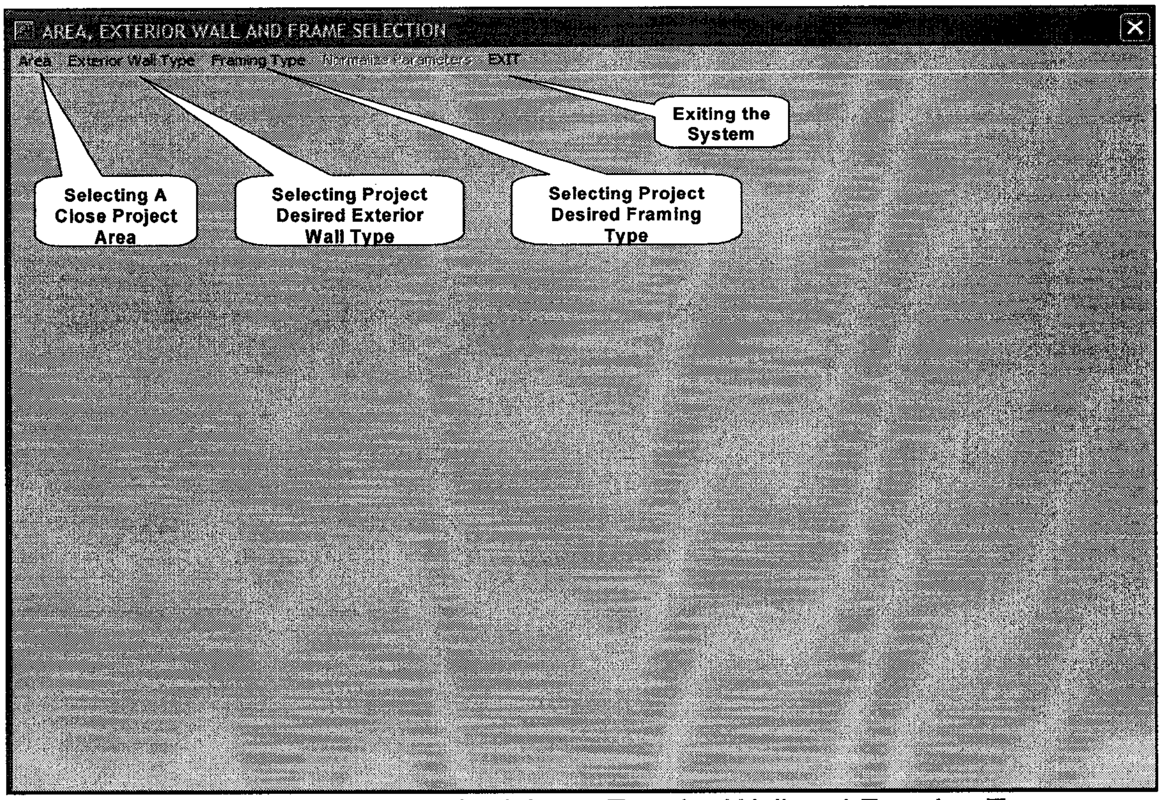


Figure 5.41 Selecting Desired Area, Exterior Wall and Framing Types

The module provides users with the option of choosing the project's area close to the proposed one, besides the desired exterior wall and framing types respectively, all depending on the project's selected type as shown in Figure 5.41. Based on the user preferences, the module retrieves all the associated data and exhibits them instantly. Figures 5.42 to 5.44 represent three different types of data supplied to the user. Moreover, if desired, the user can view the associated 3D CAD drawing by just clicking on the "Associated AutoCAD Drawing" button. In this case, the module opens the drawing in a format similar to the one shown in Figure 5.31.

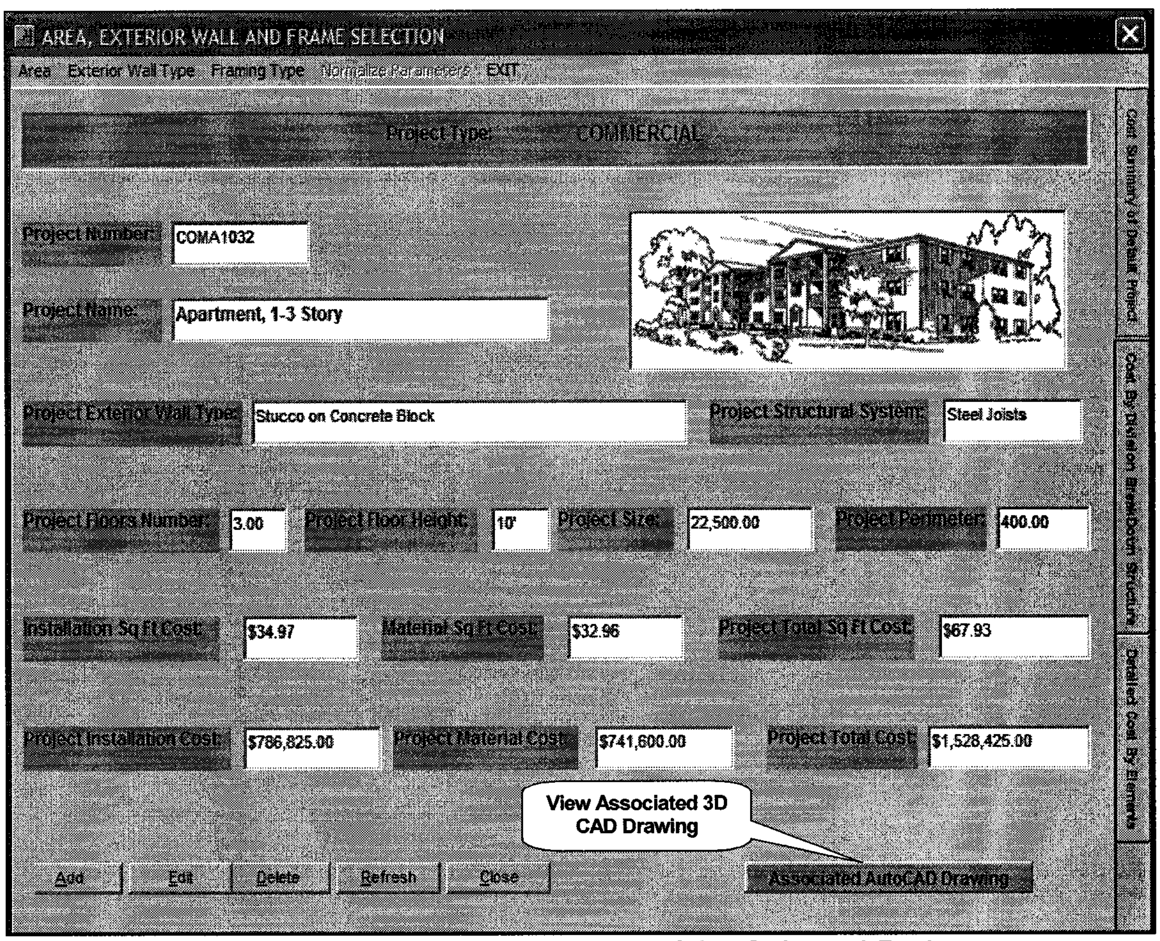
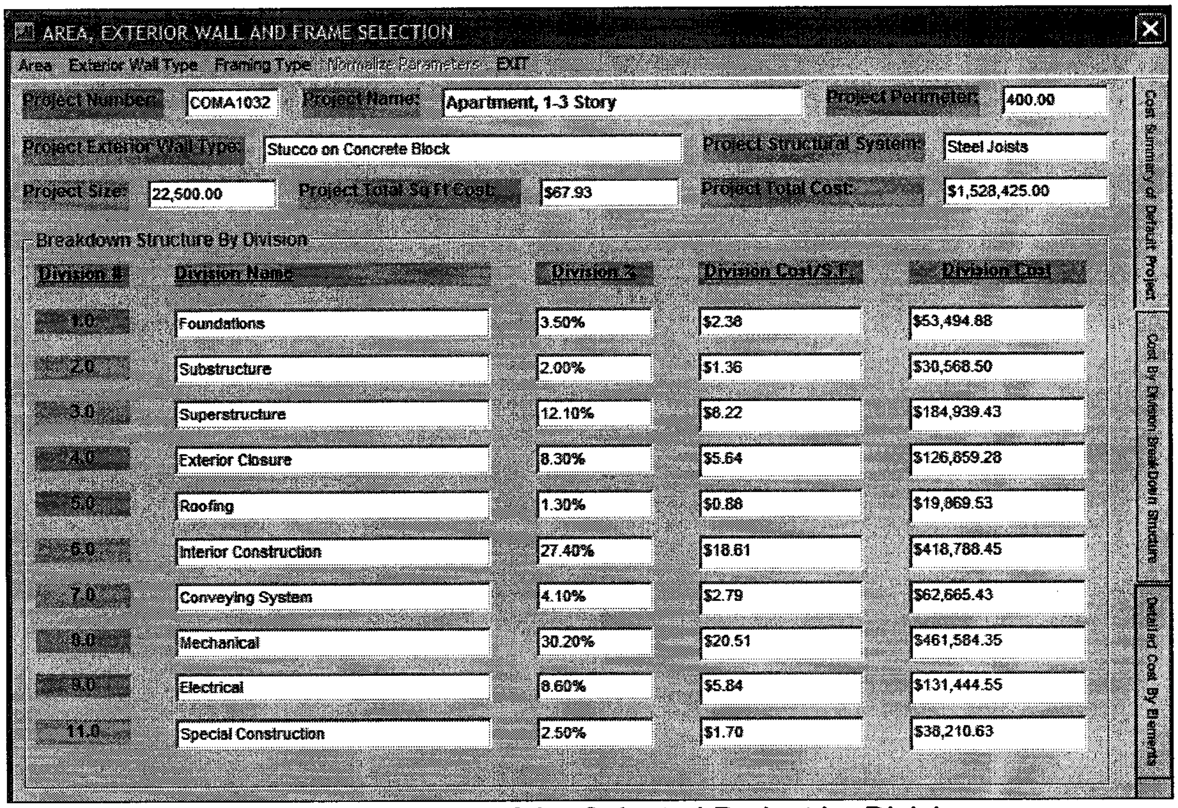


Figure 5.42 Summary Cost Data of the Selected Project



AREA, EXTERIOR WALL AND FRAME SELECTION

Area | Exterior Wall Type | Framing Type | Normalize Parameters | EXIT

Project Number: COMA1032 | Project Name: Apartment, 1-3 Story | Project Perimeter: 400.00

Project Exterior Wall Type: Stucco on Concrete Block | Project Structural System: Steel Joists

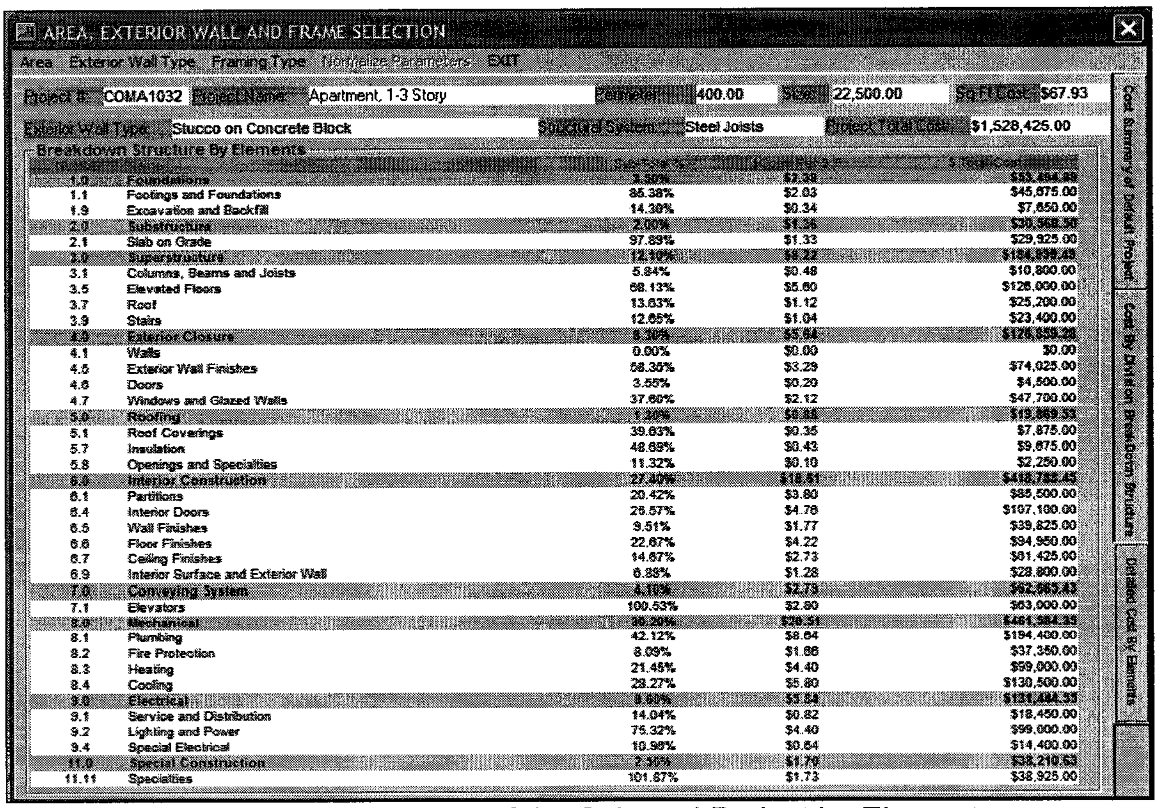
Project Size: 22,500.00 | Project Total Sq Ft Cost: $67.93 | Project Total Cost: $1,528,425.00

Breakdown Structure By Division

Division #	Division Name	Division %	Division Cost/S.F.	Division Cost
1.0	Foundations	3.50%	$2.38	$53,494.88
2.0	Substructure	2.00%	$1.36	$30,568.50
3.0	Superstructure	12.10%	$8.22	$184,939.43
4.0	Exterior Closure	8.30%	$5.64	$126,859.28
5.0	Roofing	1.30%	$0.88	$19,869.53
6.0	Interior Construction	27.40%	$18.61	$418,788.45
7.0	Conveying System	4.10%	$2.79	$62,665.43
8.0	Mechanical	30.20%	$20.51	$461,584.35
9.0	Electrical	8.60%	$5.84	$131,444.55
11.0	Special Construction	2.50%	$1.70	$38,210.63

Cost Summary of Default Project | Cost By Division Breakdown Structure | Detailed Cost By Elements

Figure 5.43 Cost Data of the Selected Project by Divisions



AREA, EXTERIOR WALL AND FRAME SELECTION

Area | Exterior Wall Type | Framing Type | Normalize Parameters | EXIT

Project #: COMA1032 | Project Name: Apartment, 1-3 Story | Perimeter: 400.00 | Size: 22,500.00 | Sq Ft Cost: $67.93

Exterior Wall Type: Stucco on Concrete Block | Structural System: Steel Joists | Project Total Cost: $1,528,425.00

Breakdown Structure By Elements

Number	Name	Sub-Total %	$ Cost Per S.F.	$ Total Cost
1.0	Foundations	3.50%	$2.38	$53,494.88
1.1	Footings and Foundations	85.38%	$2.03	$45,675.00
1.9	Excavation and Backfill	14.30%	$0.34	$7,650.00
2.0	Substructure	2.00%	$1.36	$30,568.50
2.1	Slab on Grade	97.89%	$1.33	$29,925.00
3.0	Superstructure	12.10%	$8.22	$184,939.43
3.1	Columns, Beams and Joists	5.84%	$0.48	$10,800.00
3.5	Elevated Floors	68.13%	$5.60	$126,000.00
3.7	Roof	13.63%	$1.12	$25,200.00
3.9	Stairs	12.65%	$1.04	$23,400.00
4.0	Exterior Closure	8.30%	$5.64	$126,859.28
4.1	Walls	0.00%	$0.00	$0.00
4.5	Exterior Wall Finishes	58.35%	$3.29	$74,025.00
4.6	Doors	3.55%	$0.20	$4,500.00
4.7	Windows and Glazed Walls	37.60%	$2.12	$47,700.00
5.0	Roofing	1.30%	$0.88	$19,869.53
5.1	Roof Coverings	39.63%	$0.35	$7,875.00
5.7	Insulation	48.69%	$0.43	$9,675.00
5.8	Openings and Specialties	11.32%	$0.10	$2,250.00
6.0	Interior Construction	27.40%	$18.61	$418,788.45
6.1	Partitions	20.42%	$3.80	$85,500.00
6.4	Interior Doors	25.57%	$4.76	$107,100.00
6.5	Wall Finishes	9.51%	$1.77	$39,825.00
6.6	Floor Finishes	22.67%	$4.22	$94,950.00
6.7	Ceiling Finishes	14.67%	$2.73	$61,425.00
6.9	Interior Surface and Exterior Wall	6.88%	$1.28	$28,800.00
7.0	Conveying System	4.10%	$2.79	$62,665.43
7.1	Elevators	100.53%	$2.80	$63,000.00
8.0	Mechanical	30.20%	$20.51	$461,584.35
8.1	Plumbing	42.12%	$8.64	$194,400.00
8.2	Fire Protection	8.09%	$1.66	$37,350.00
8.3	Heating	21.45%	$4.40	$99,000.00
8.4	Cooling	28.27%	$5.80	$130,500.00
9.0	Electrical	8.60%	$5.84	$131,444.55
9.1	Service and Distribution	14.04%	$0.82	$18,450.00
9.2	Lighting and Power	75.32%	$4.40	$99,000.00
9.4	Special Electrical	10.96%	$0.64	$14,400.00
11.0	Special Construction	2.50%	$1.70	$38,210.63
11.11	Specialties	101.87%	$1.73	$38,925.00

Cost Summary of Default Project | Cost By Division Breakdown Structure | Detailed Cost By Elements

Figure 5.44 Cost Data of the Selected Project by Elements

If any modifications are made, and the new parameters are written to the database, the module offers the user the option of automatically effecting all necessary adjustments one after the other. Clicking the “Normalize Parameters” top menu starts these procedures as exemplified in Figure 5.45.

- First, costs are adjusted for size, using the equations derived in Chapter Four section 4.6.1. The module executes this adjustment automatically after the user clicks the “Adjust for Size” top menu as seen in Figure 5.46.

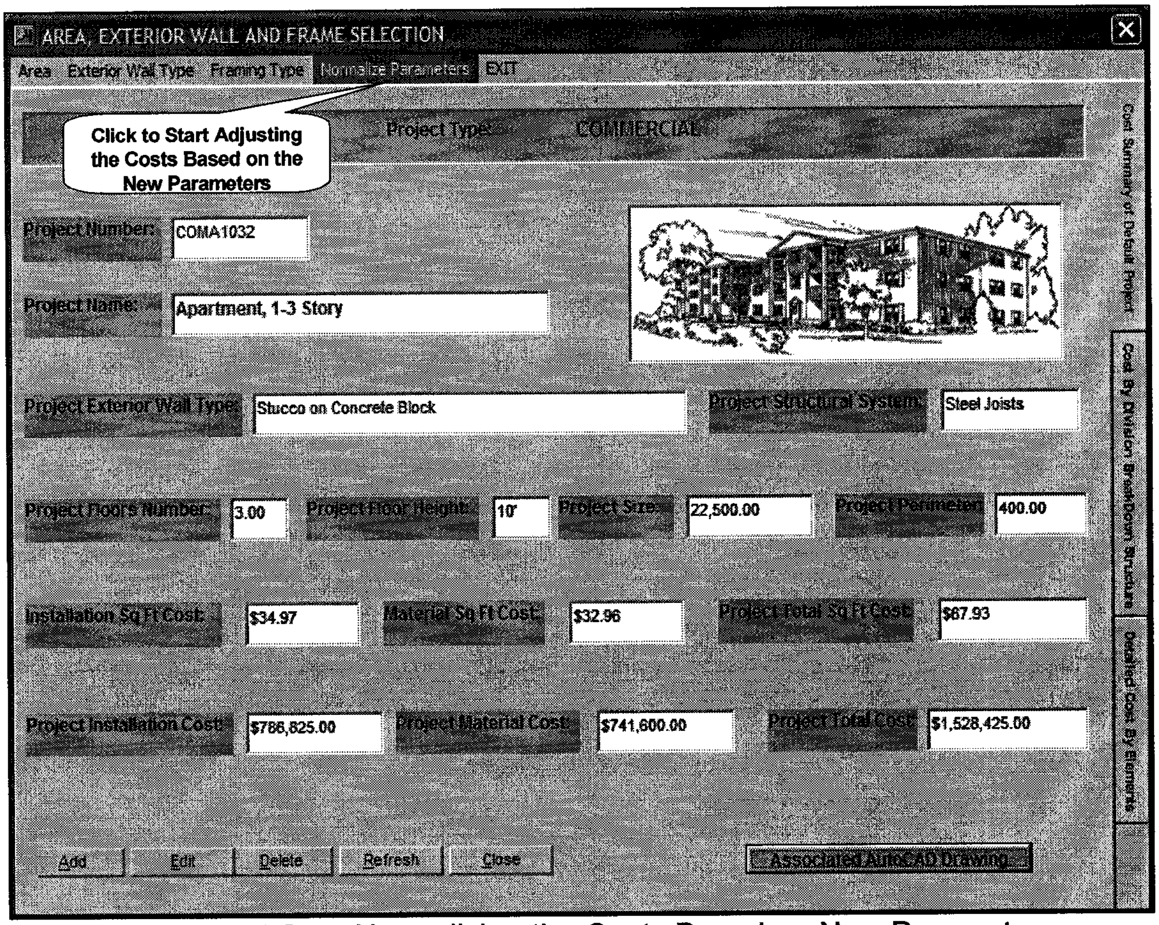


Figure 5.45 Start Normalizing the Costs Based on New Parameters

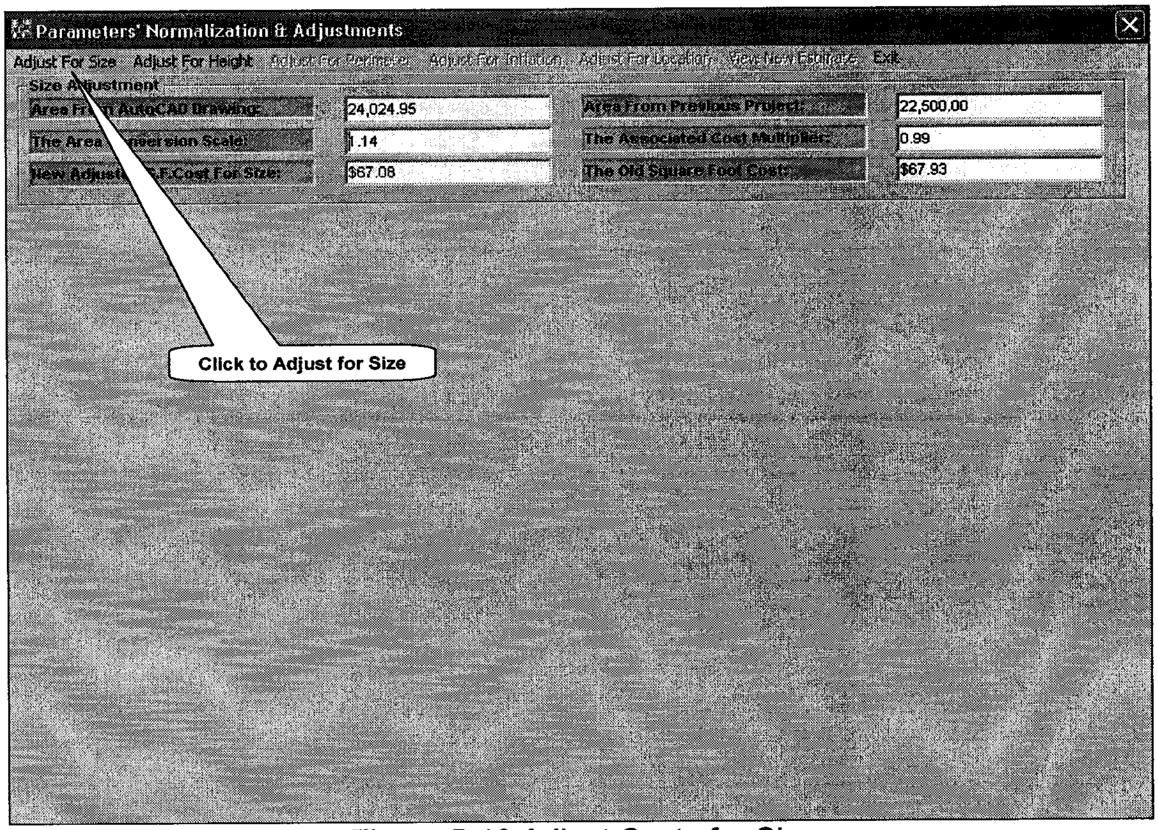


Figure 5.46 Adjust Costs for Size

- Second, the new adjusted costs for size are further adjusted for height difference following the same procedures discussed in Chapter Four section 4.6.2. The module instantly carries out these adjustments once the “Adjust for Height” top menu is hit as illustrated in Figure 5.47.
- Third, the resulting adjusted costs for height are further adjusted for Perimeter, pursuing the same measures as explained in Chapter Four section 4.6.3. The module makes these adjustments directly after clicking on the “Adjust for Perimeter” top menu as seen in Figure 5.48.
- Fourth, the computed adjusted costs for perimeter are afterwards adjusted for inflation as soon as the user inputs the inflation rate and the number of years. This adjustment is done using the equation [4.10] in Chapter Four

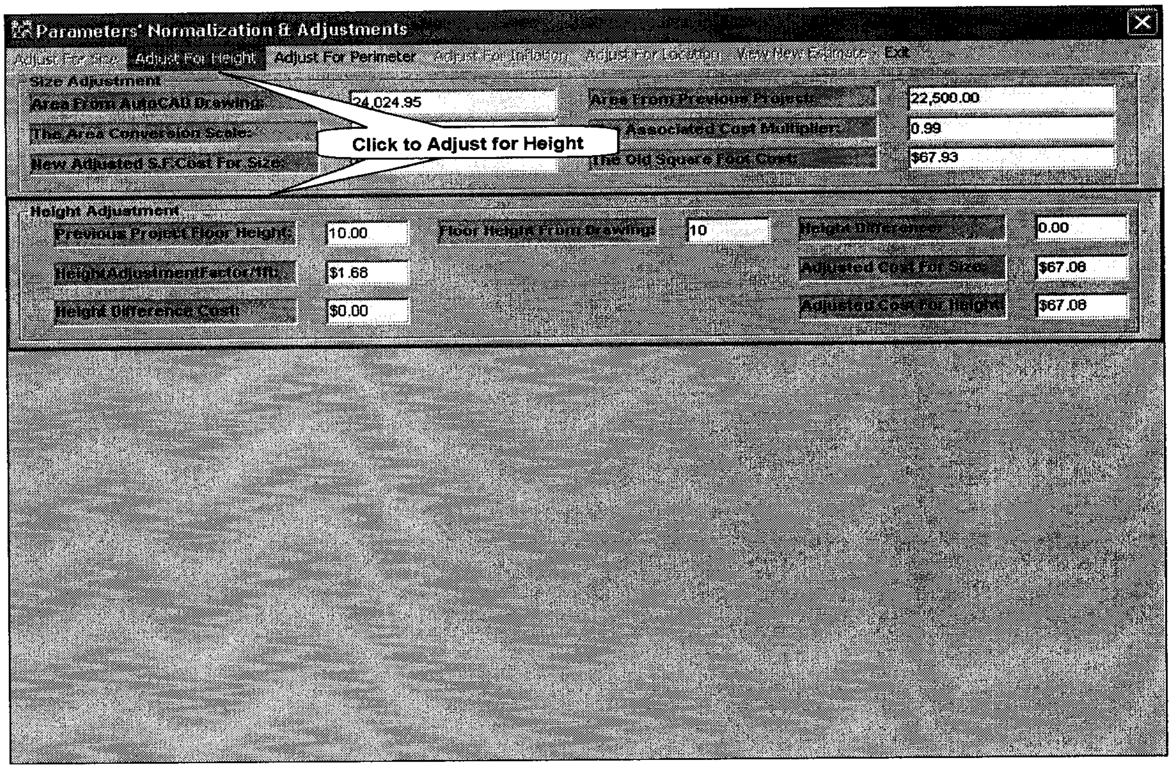


Figure 5.47 Adjust Costs for Height

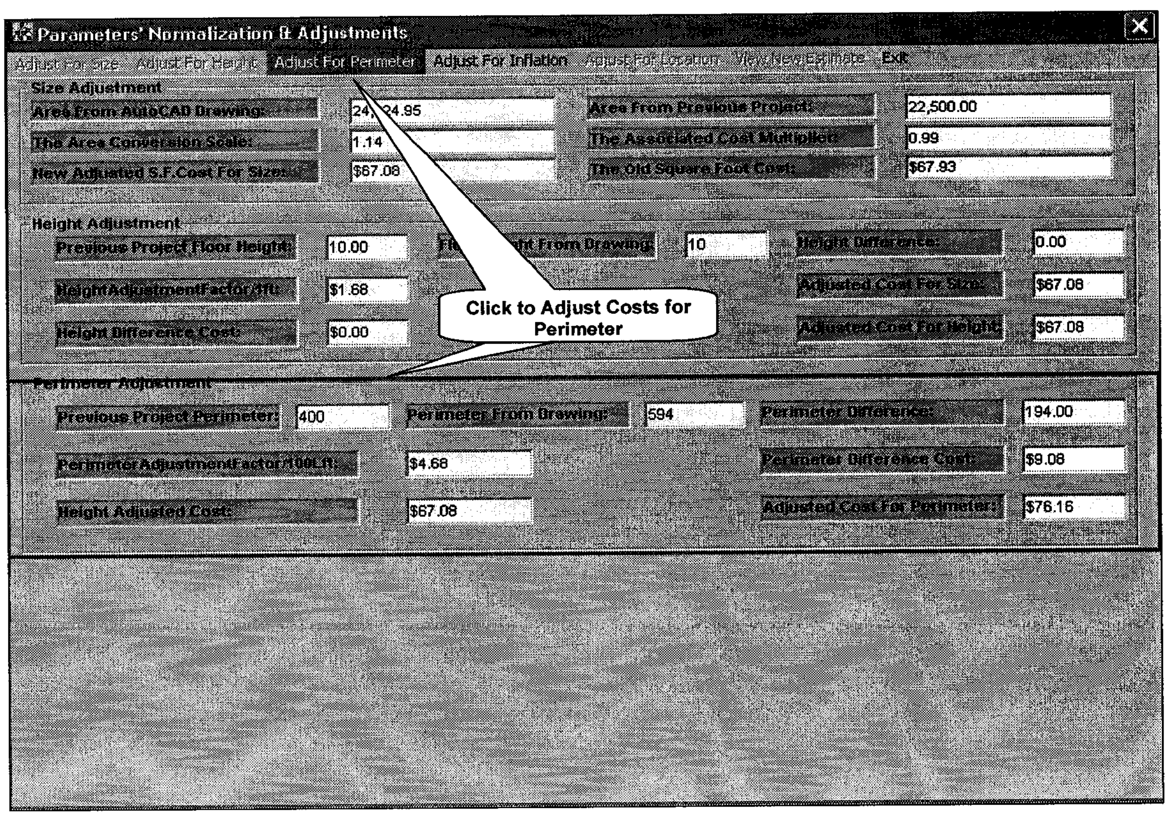


Figure 5.48 Adjust Costs for Perimeter

section 4.6.4 immediately after clicking the "Adjust for Inflation" top menu as Figure 5.49 exemplifies.

- Fifth, the new costs determined in the previous step are further adjusted for city location once the user hits the "Adjust for Location" top menu using the equation [4.11] of Chapter Four section 4.6.5 and selecting the city. The module provides the user with a value of the city location factor, which can be changed if necessary. Clicking the "OK" button instructs the module to execute the required adjustments and provides the final costs as shown in Figure 5.50.

At this stage, the module provides the user with the option of visualizing the proposed project's new cost estimate after all necessary adjustments are done.

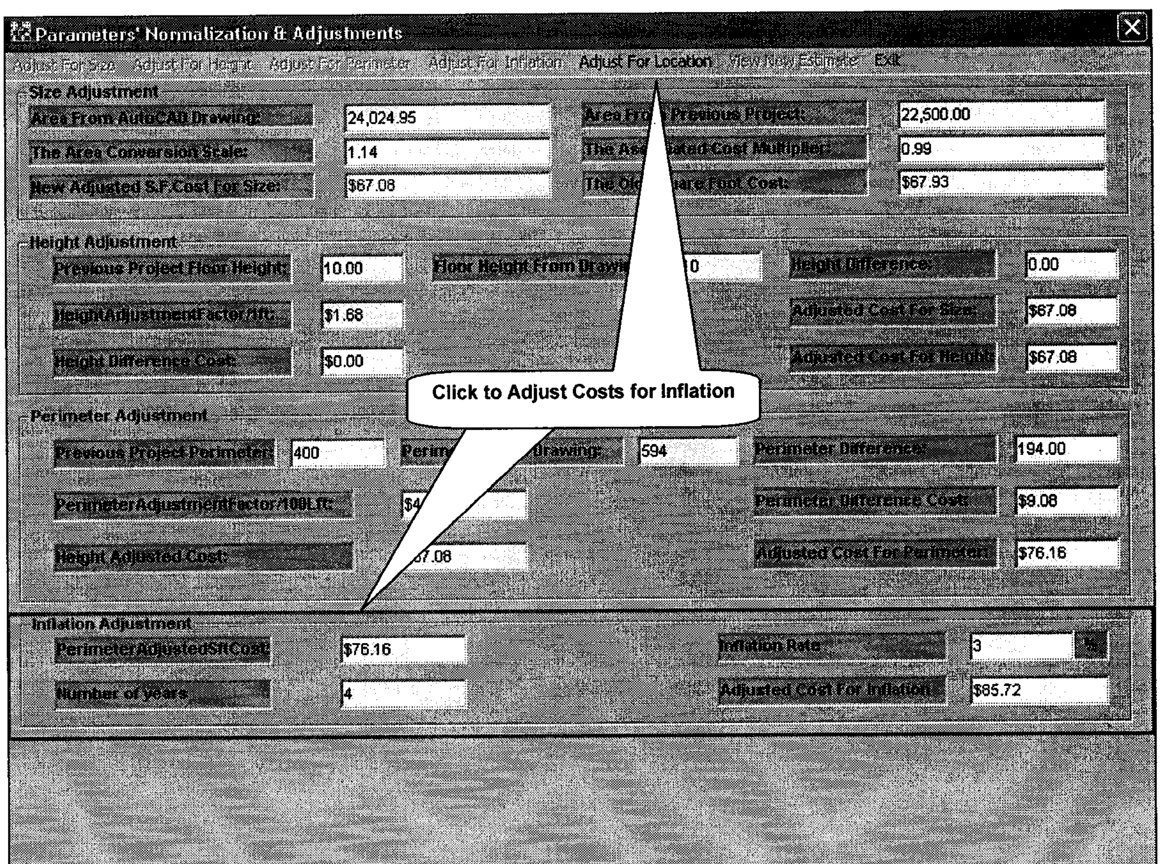


Figure 5.49 Adjust Costs for Inflation

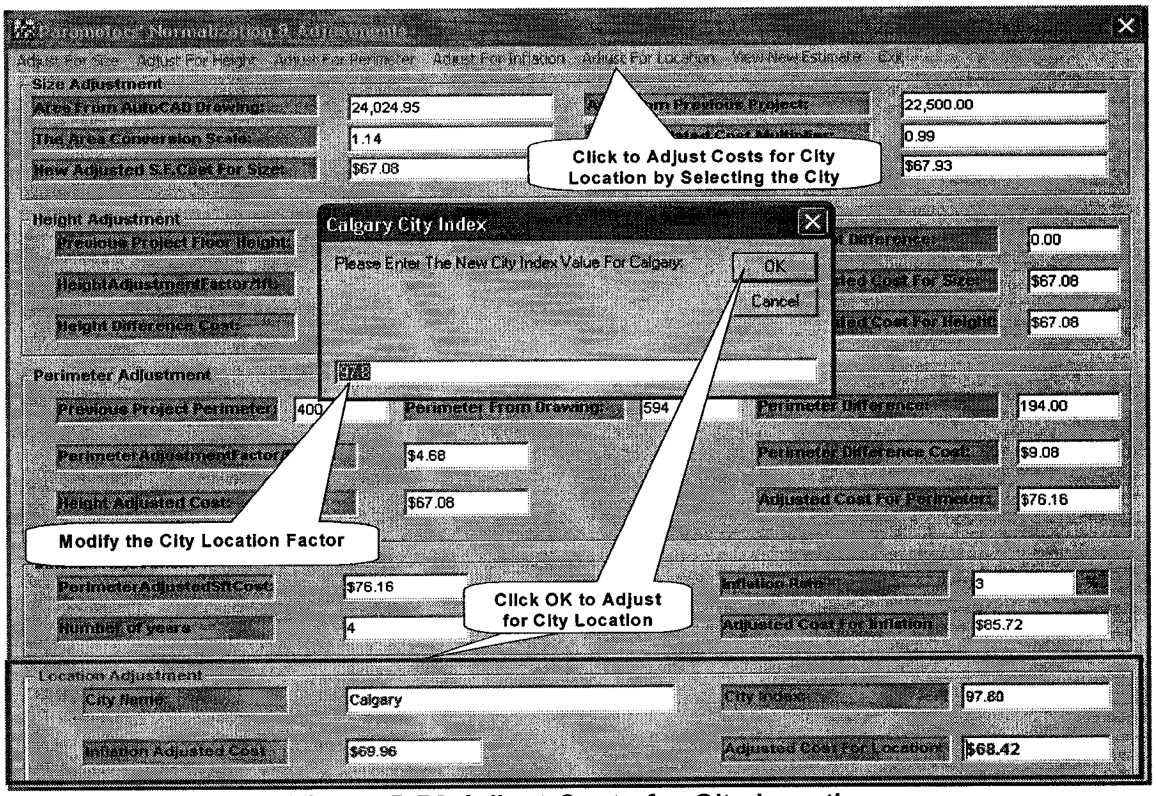


Figure 5.50 Adjust Costs for City Location

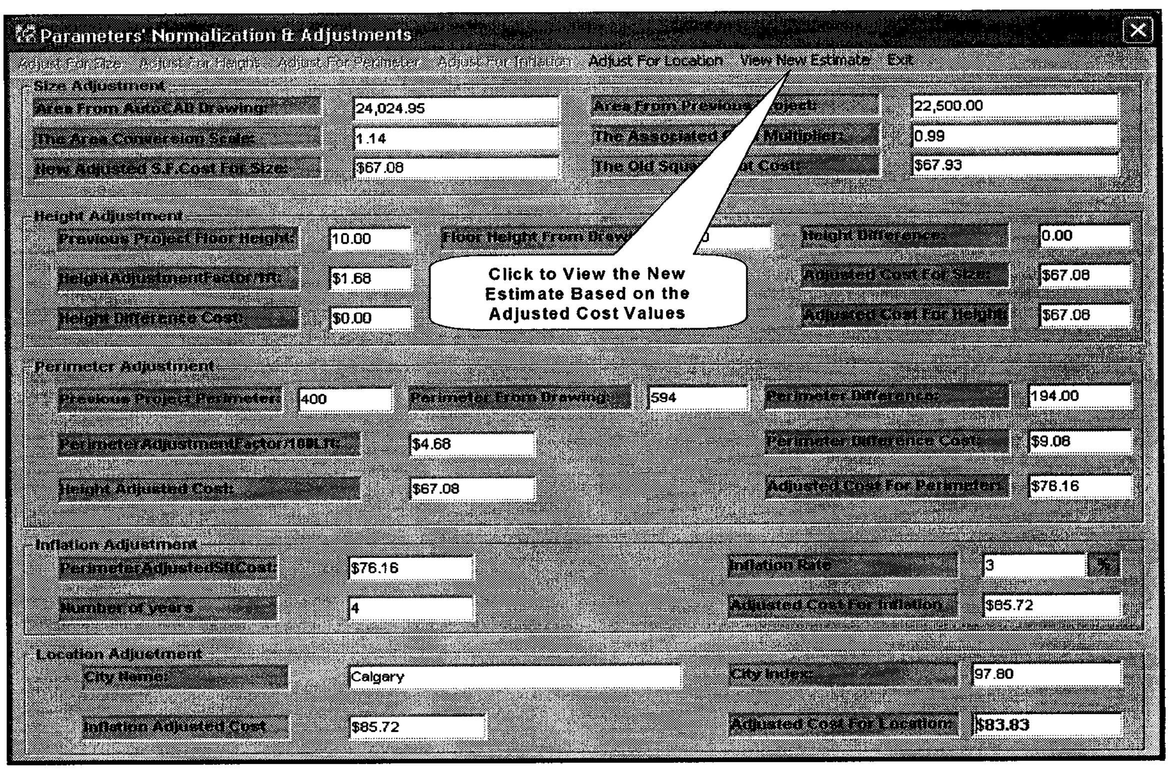


Figure 5.51 View New Estimate Based on Adjusted Costs

This is achieved by selecting the "View New Estimate" top menu as shown in Figure 5.51. Similar to Figures 5.42 to 5.44, three different types of cost data are provided in addition to the option of visualizing the project in Virtual Reality and its associated cost data before and after the drawing modification. Once the user is satisfied with the new estimated cost values, he/she can choose to input the indirect costs. This is accounted in Figure 5.52 by clicking the "Indirect Costs" top menu. The module incorporates inherited values for the indirect costs. However, the user can modify these values if required. By hitting the "OK" button the module provides the user with a selection list of pre-formatted output reports similar to the one shown in Figure 5.23. As mentioned earlier, these reports are better illustrated in Chapter Six the System Performance.

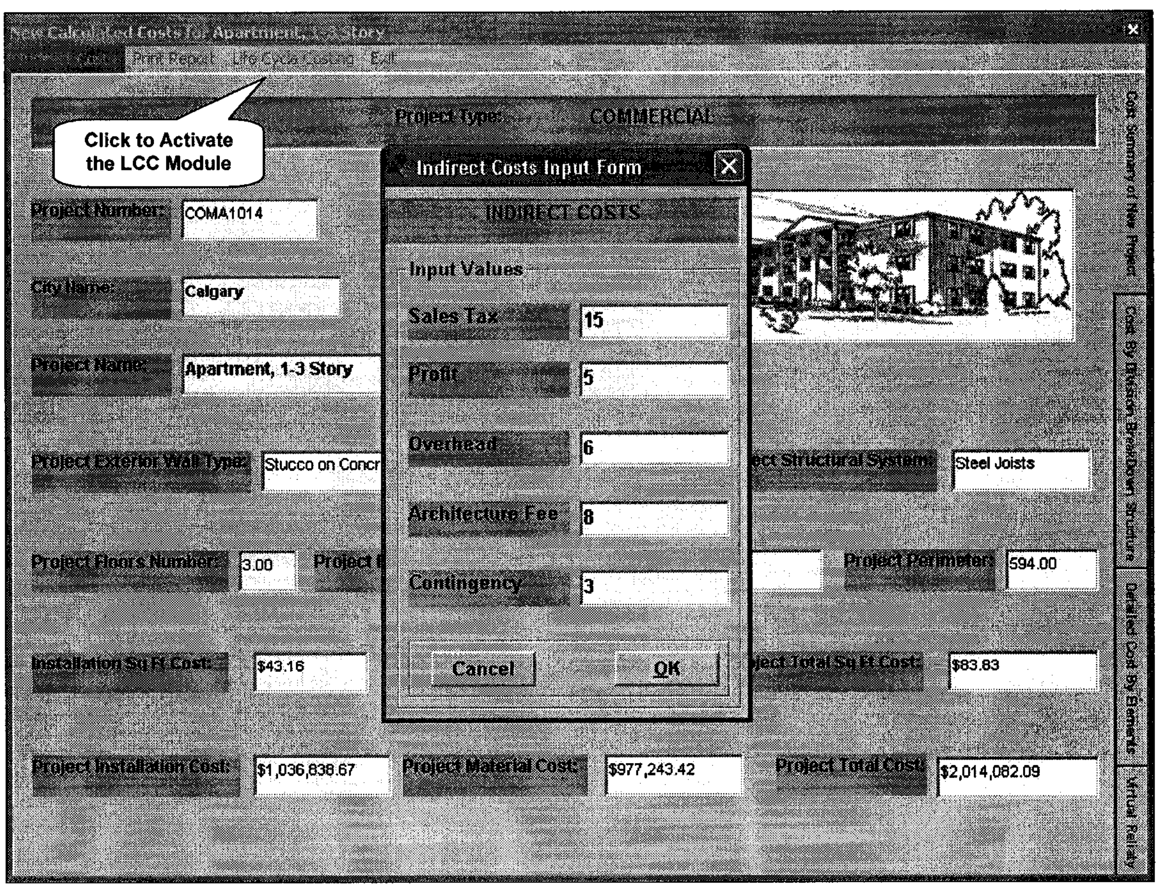


Figure 5.52 Inputting the Indirect Costs

In this way the development's requirements for this module are fulfilled. Nevertheless, if the user requests a forecast of the future costs of running the proposed building as well as the anticipated income, the module offers the option of activating the LCC module instantly after clicking the "Life Cycle Costing" top menu as pictured in Figure 5.52.

5.5 LCC & Sensitivity Analysis Modules' Development (Phase 4)

This module is integrated with the LCC database, which has its information supplied by the global module. Once the module is activated, the user is provided with a form displaying all the proposed project's information and costs derived from previous modules. Furthermore, the module retrieves all essential adjustment factors related to the proposed project and city. However, the user has to fill in some data required by the module to execute the forecast as seen in Figure 5.53. After these data are entered, the top menu button "Continue" is enabled as shown in Figure 5.54. If this button is clicked, the module is instructed to start the forecasting procedures and execute all necessary calculations.

Equations [4.12], [4.13] and [4.14] derived in Chapter Four are used in the LCC module, which uses them to calculate the expected values for rent, retail and TOEFEL and accordingly writes these values to the assigned tables in the LCC database. Once these data are stored in the database, several calculations are made in the back-end by series of queries designed for these purposes.

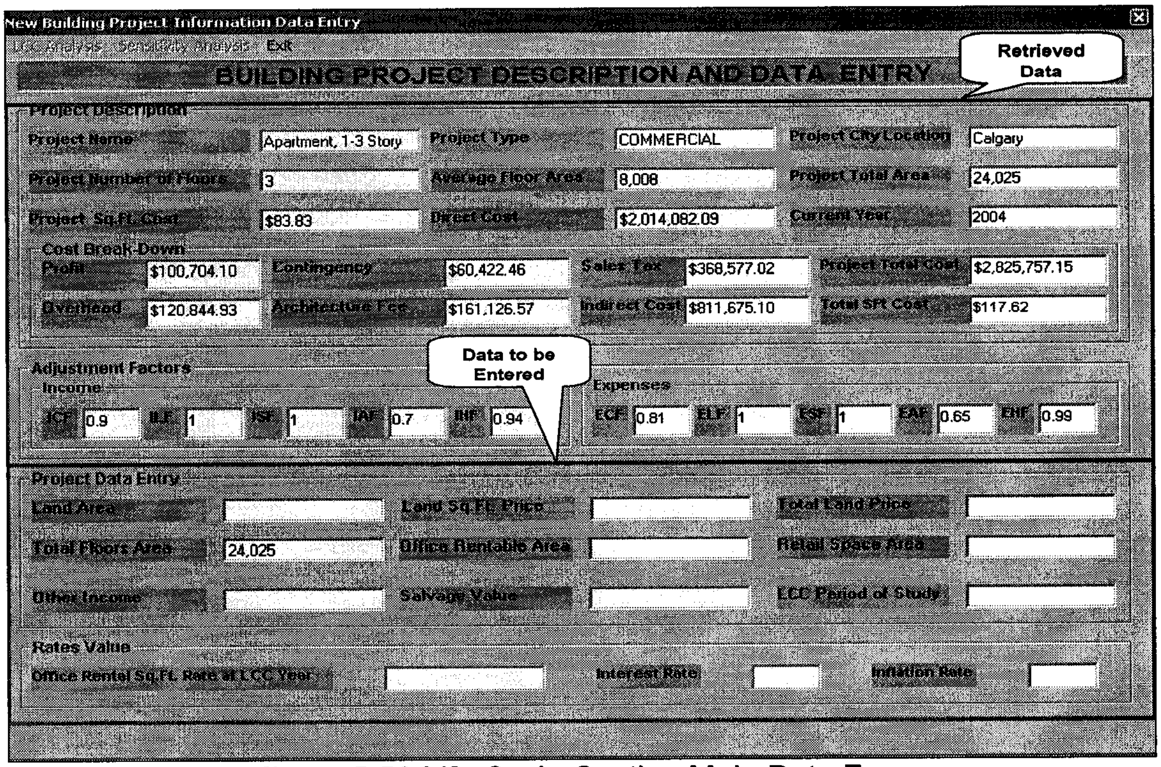


Figure 5.53 Life Cycle Costing Main Data Form

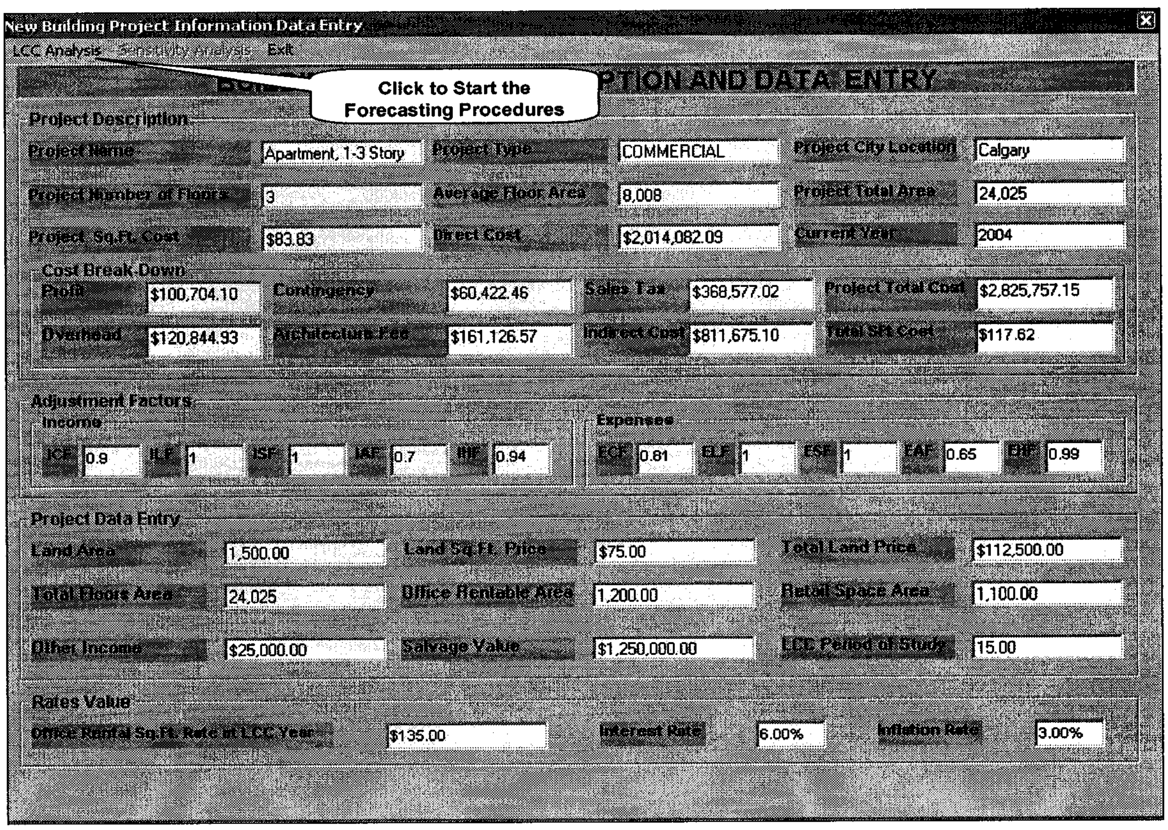


Figure 5.54 Filling-out the Required Data to Start the Forecast

This process takes a few seconds. Then the module offers the user a list of preformatted output reports to select from as shown in Figure 5.24. These output reports include: 1) Expenses Percentage Cost Item Break-Down; 2) Life Cycle Costing Analysis; 3) Net Operating Income Results; 4) Total Expenses Cash Flow Calculation Results; 5) Total Income Cash Flow Calculation Results, which are given in detail in Chapter Six.

Instantaneously after finishing the reports' selection process, the module enables the "Sensitivity Analysis" top menu button offering users the choice of identifying the most sensitive parameters as observed in Figure 5.55.

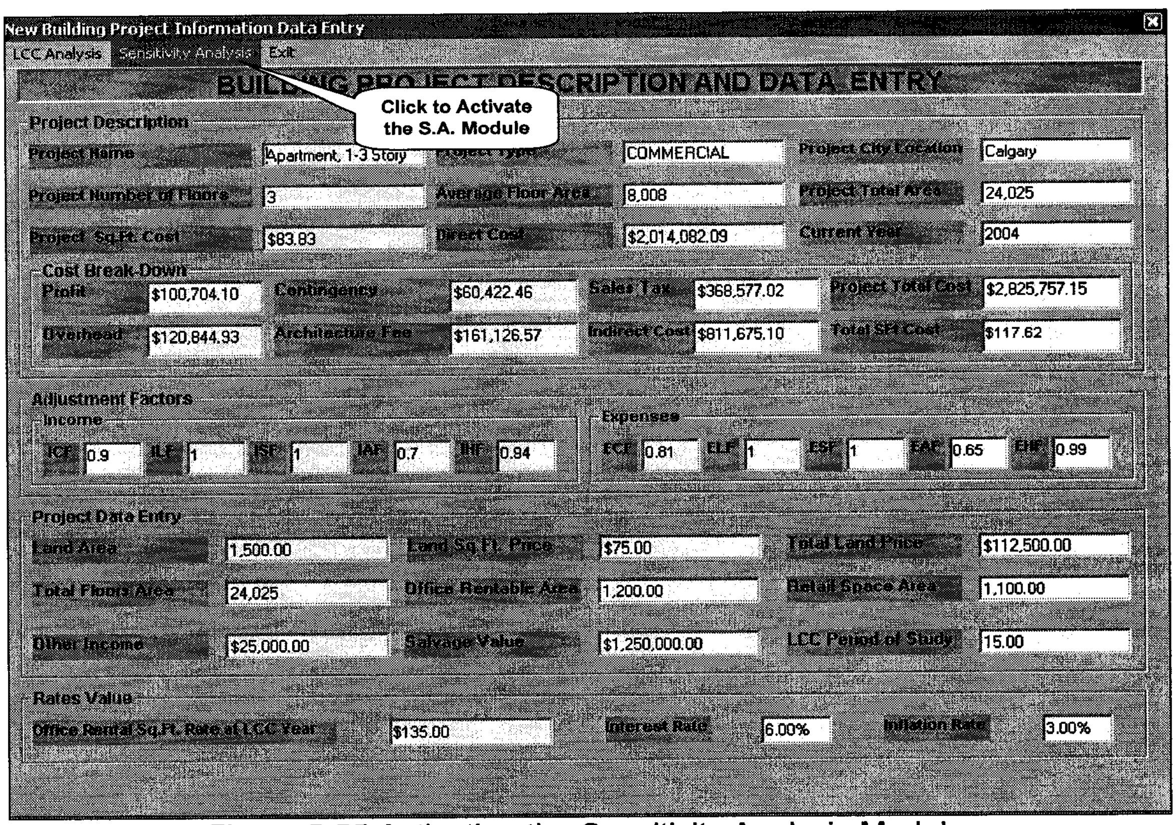


Figure 5.55 Activating the Sensitivity Analysis Module

Once this button is hit, the Sensitivity Analysis (S.A.) module is activated and all the forecasted values executed by the LCC module are written in the S.A. database. Subsequently, the S.A. module requests the user to enter the deviation of errors and the related step to be considered in the S.A. method by showing a form as shown in Figure 5.56. Entering those values and clicking the "OK" button direct the module to write them into the S.A. database and open its integrated interface by showing the form illustrated in Figure 5.25. During the process of loading that form, numerous calculations are executed in the background. As mentioned earlier in section 5.2.5, if the "Analyze" button is clicked, the interface is ordered to calculate the NPV taking into consideration parameters in the list. Accordingly these values are sent in a tabulated format to the spreadsheet (MS Excel).

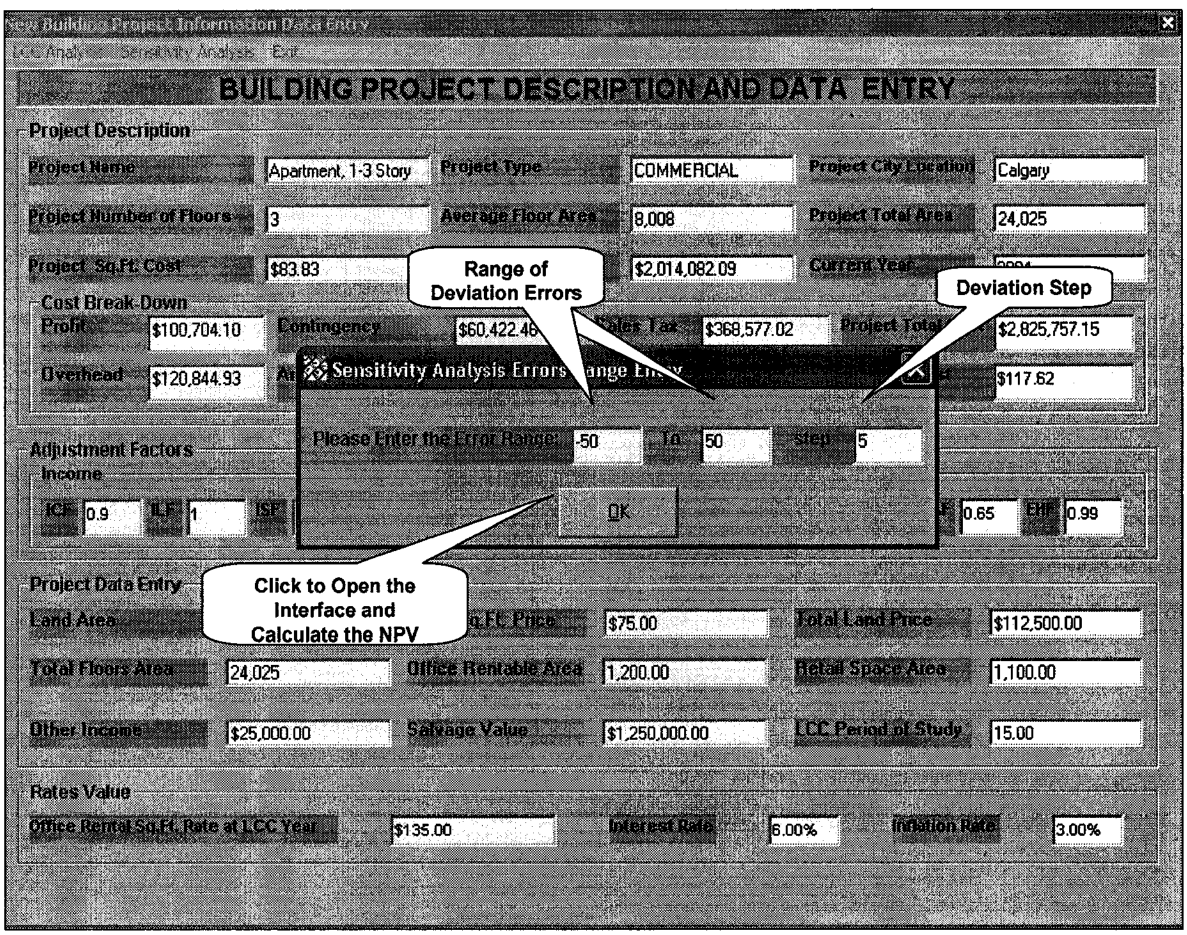
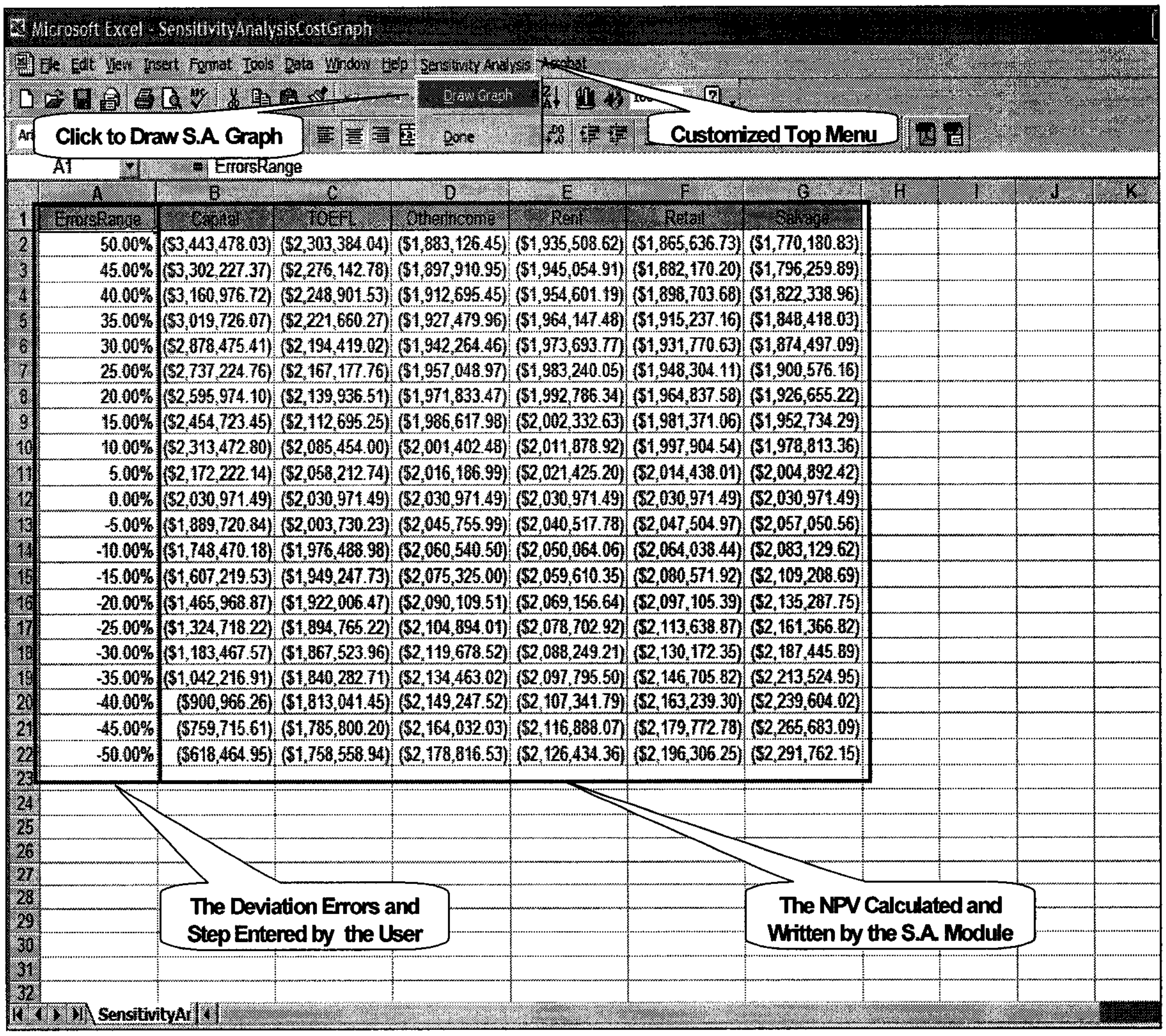


Figure 5.56 Entering the Range of Deviation and Associated Step

Nevertheless, in order to automate the process of preparing the sensitivity graphs, MS Excel has been customized to fit the modularity requirements of the system. For that reason, a new global drop-down menu called "Sensitivity Analysis" has been created, which users can employ to execute the foregoing procedure as exemplified in Figure 5.57. Clicking the "Draw Graph" button instructs the VBA module that has been written in Excel to draw the graph instantly based on the NPV data source written by the S.A. module in the worksheet as seen in Figure 5.58.



ErrorsRange	Capital	TOEFL	OtherIncome	Rent	Retail	Salvage
50.00%	($3,443,478.03)	($2,303,384.04)	($1,883,126.45)	($1,935,508.62)	($1,865,636.73)	($1,770,180.83)
45.00%	($3,302,227.37)	($2,276,142.78)	($1,897,910.95)	($1,945,054.91)	($1,882,170.20)	($1,796,259.89)
40.00%	($3,160,976.72)	($2,248,901.53)	($1,912,695.45)	($1,954,601.19)	($1,898,703.68)	($1,822,338.96)
35.00%	($3,019,726.07)	($2,221,660.27)	($1,927,479.96)	($1,964,147.48)	($1,915,237.16)	($1,848,418.03)
30.00%	($2,878,475.41)	($2,194,419.02)	($1,942,264.46)	($1,973,693.77)	($1,931,770.63)	($1,874,497.09)
25.00%	($2,737,224.76)	($2,167,177.76)	($1,957,048.97)	($1,983,240.05)	($1,948,304.11)	($1,900,576.16)
20.00%	($2,595,974.10)	($2,139,936.51)	($1,971,833.47)	($1,992,786.34)	($1,964,837.58)	($1,926,655.22)
15.00%	($2,454,723.45)	($2,112,695.25)	($1,986,617.98)	($2,002,332.63)	($1,981,371.06)	($1,952,734.29)
10.00%	($2,313,472.80)	($2,085,454.00)	($2,001,402.48)	($2,011,878.92)	($1,997,904.54)	($1,978,813.36)
5.00%	($2,172,222.14)	($2,058,212.74)	($2,016,186.99)	($2,021,425.20)	($2,014,438.01)	($2,004,892.42)
0.00%	($2,030,971.49)	($2,030,971.49)	($2,030,971.49)	($2,030,971.49)	($2,030,971.49)	($2,030,971.49)
-5.00%	($1,889,720.84)	($2,003,730.23)	($2,045,755.99)	($2,040,517.78)	($2,047,504.97)	($2,057,050.56)
-10.00%	($1,748,470.18)	($1,976,488.98)	($2,060,540.50)	($2,050,064.06)	($2,064,038.44)	($2,083,129.62)
-15.00%	($1,607,219.53)	($1,949,247.73)	($2,075,325.00)	($2,059,610.35)	($2,080,571.92)	($2,109,208.69)
-20.00%	($1,465,968.87)	($1,922,006.47)	($2,090,109.51)	($2,069,156.64)	($2,097,105.39)	($2,135,287.75)
-25.00%	($1,324,718.22)	($1,894,765.22)	($2,104,894.01)	($2,078,702.92)	($2,113,638.87)	($2,161,366.82)
-30.00%	($1,183,467.57)	($1,867,523.96)	($2,119,678.52)	($2,088,249.21)	($2,130,172.35)	($2,187,445.89)
-35.00%	($1,042,216.91)	($1,840,282.71)	($2,134,463.02)	($2,097,795.50)	($2,146,705.82)	($2,213,524.95)
-40.00%	($900,966.26)	($1,813,041.45)	($2,149,247.52)	($2,107,341.79)	($2,163,239.30)	($2,239,604.02)
-45.00%	($759,715.61)	($1,785,800.20)	($2,164,032.03)	($2,116,888.07)	($2,179,772.78)	($2,265,683.09)
-50.00%	($618,464.95)	($1,758,558.94)	($2,178,816.53)	($2,126,434.36)	($2,196,306.25)	($2,291,762.15)

Figure 5.57 Excel Customized Top Menu and Written Values

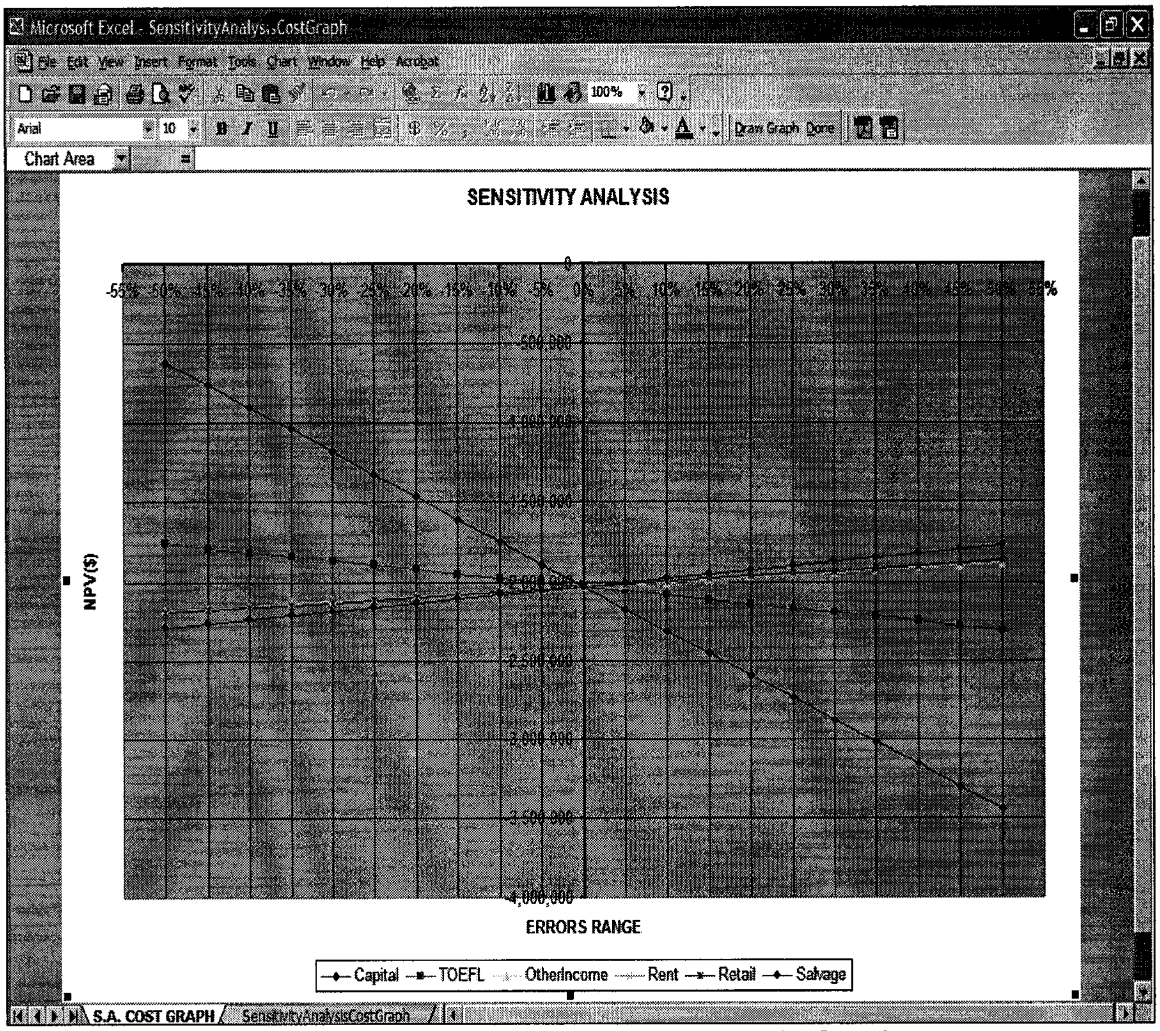


Figure 5.58 Drawn Sensitivity Analysis Graph

5.6 Forecasting & DSS Modules' Development (Phase 5)

As described in Chapter Four, this module integrates three different sub-modules that use linear regression equations to forecast the costs of proposed projects based on size or budget entry. In addition to providing a DSS that can be used by users to select the optimum project based on their budget entry. Hence, following the same procedures used in Chapter Four, the implementation of this module is going to be divided into three steps. However, all these sub-modules are accessed from the gateway module described in paragraph 5.4.

5.6.1 Sub-Module Based on Size Entry

To simplify the activation of this sub-module users utilize the entryway form of phase (3) by making a combination of selections that include the estimate type, WBS, unit, cost data type, and estimating tools as shown in Figure 5.59.

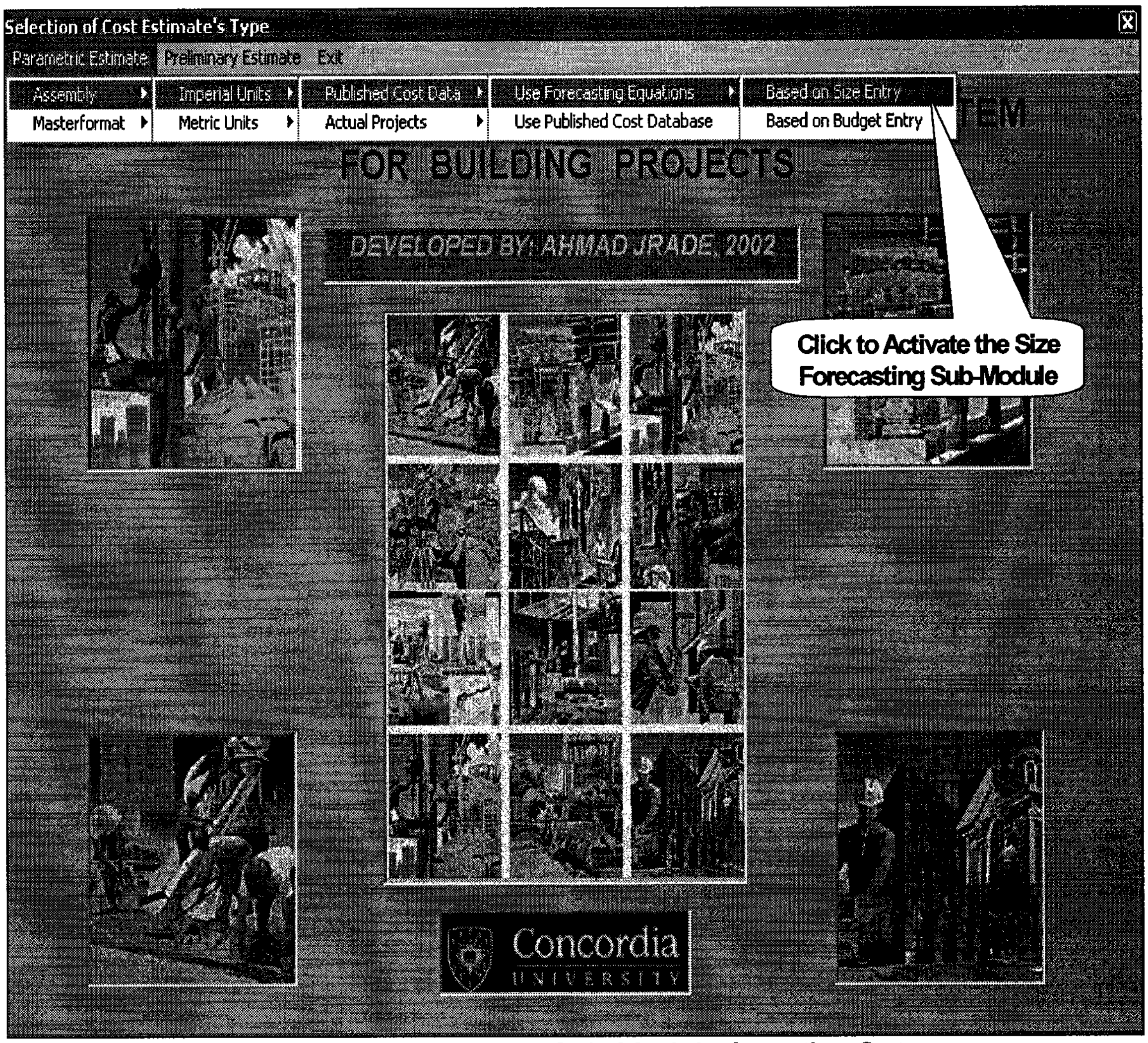


Figure 5.59 Accessing the Sub-Module from the Gateway

As soon as the user clicks on "Based on Size Entry", the system activates the sub-module and accordingly opens a form asking to select the type and category of the proposed project as given in Figure 5.60. Users then have to choose the area, exterior wall and framing type as shown in Figure 5.61 so that the system

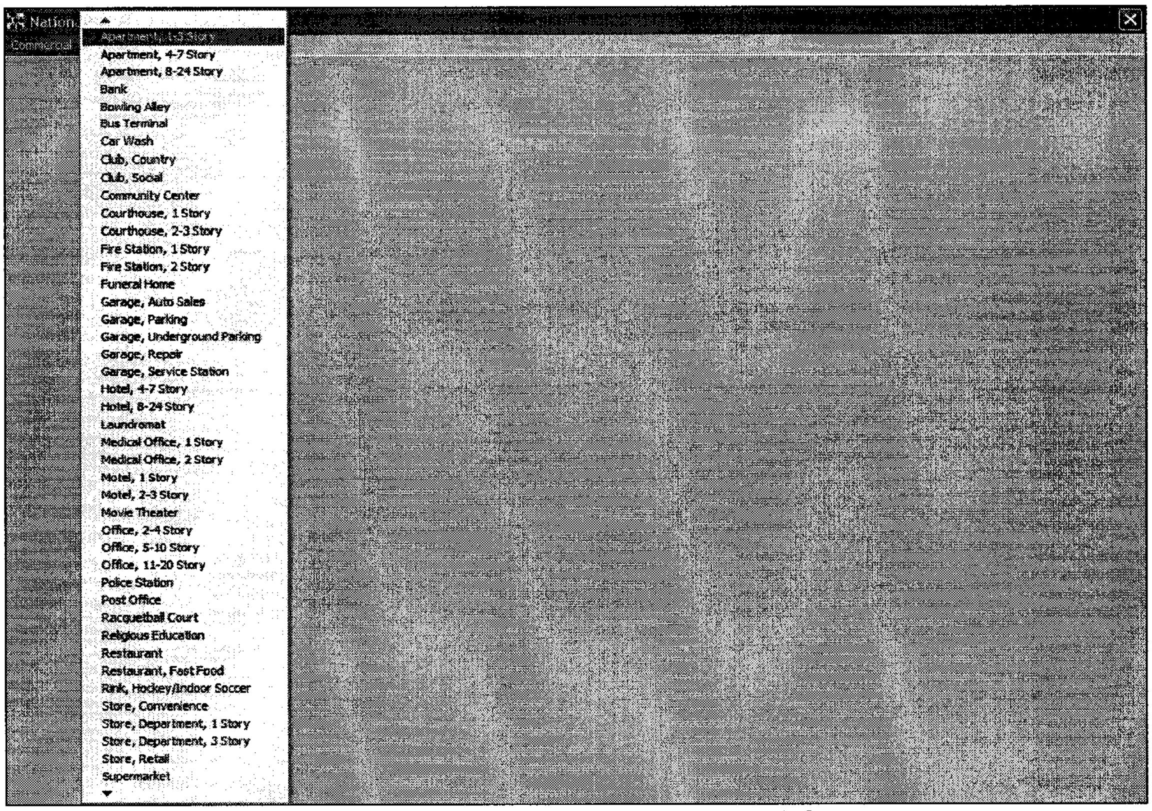


Figure 5.60 Selecting Project Type and Category

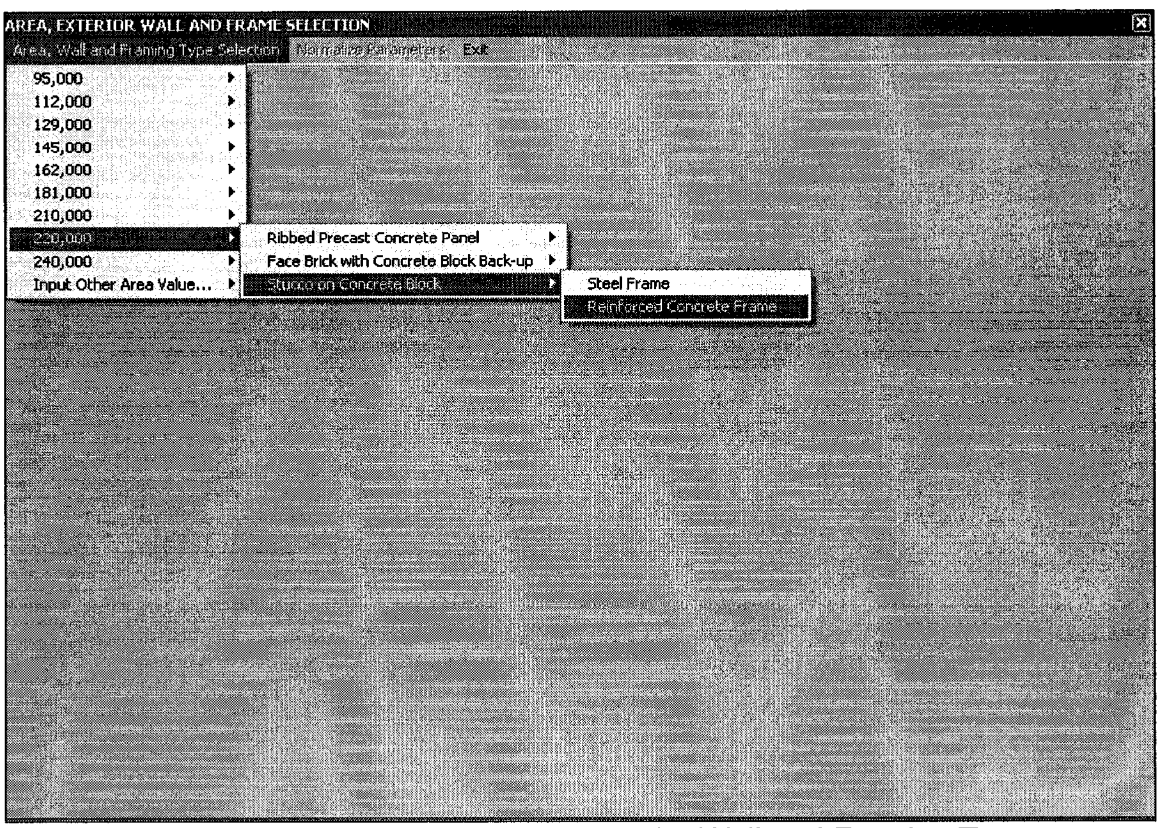


Figure 5.61 Selecting the Area, Exterior Wall and Framing Type

forecasts the cost estimate of the selected project using the equations derived in paragraph 4.8.1 of Chapter Four. All the forecasted costs are provided in three different formats, Figure 5.62 shows a summary format that users are provided with by the system, whereas the other two formats are similar to those shown in Figures 5.43 and 5.44.

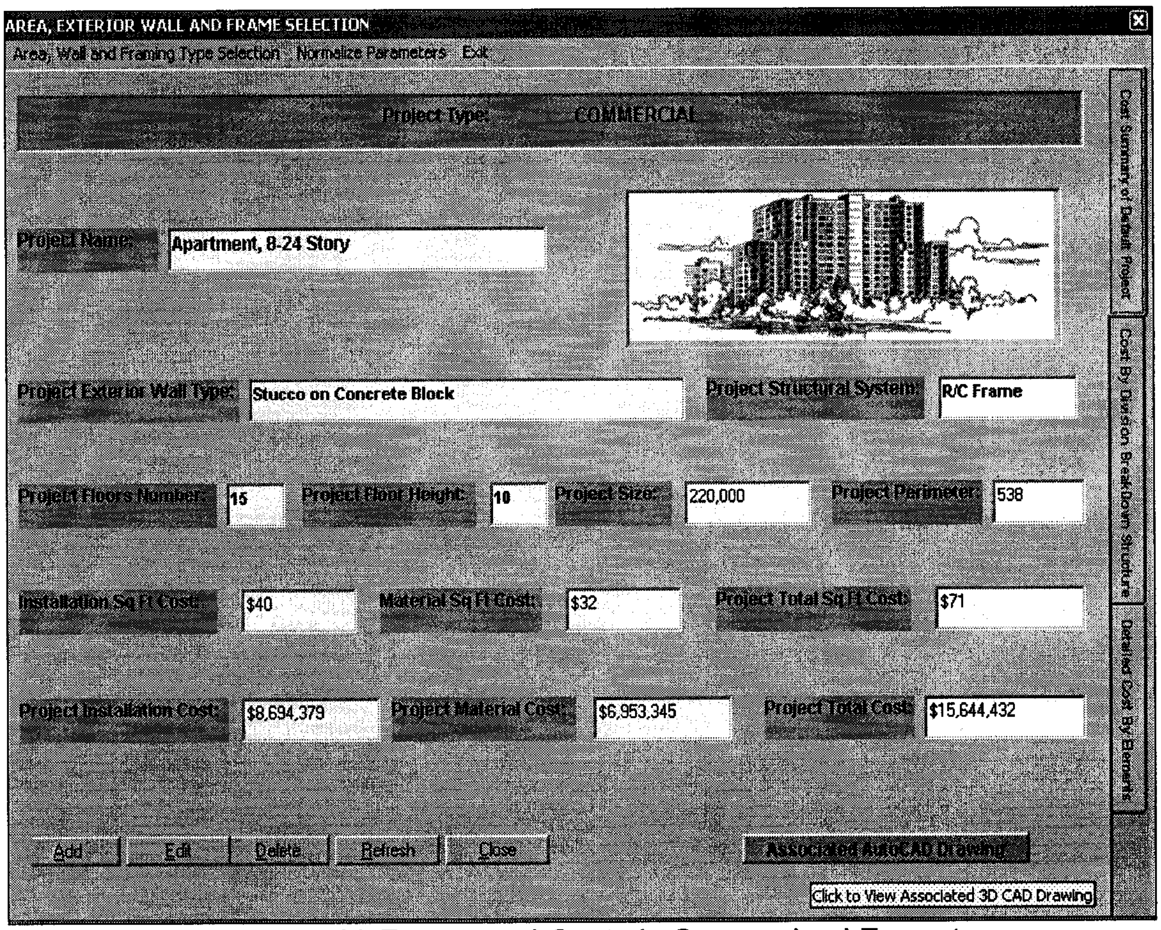


Figure 5.62 Forecasted Costs in Summarized Format

From the form shown in Figure 5.62, users can visualize the associated 3D-CAD drawing for animation and modification. For this purpose, numbers of 3D-CAD drawings have been made available to users to execute that task. Nevertheless, the system will automatically select the drawing that has a total floor area similar to the selected one as displayed in Figure 5.63.

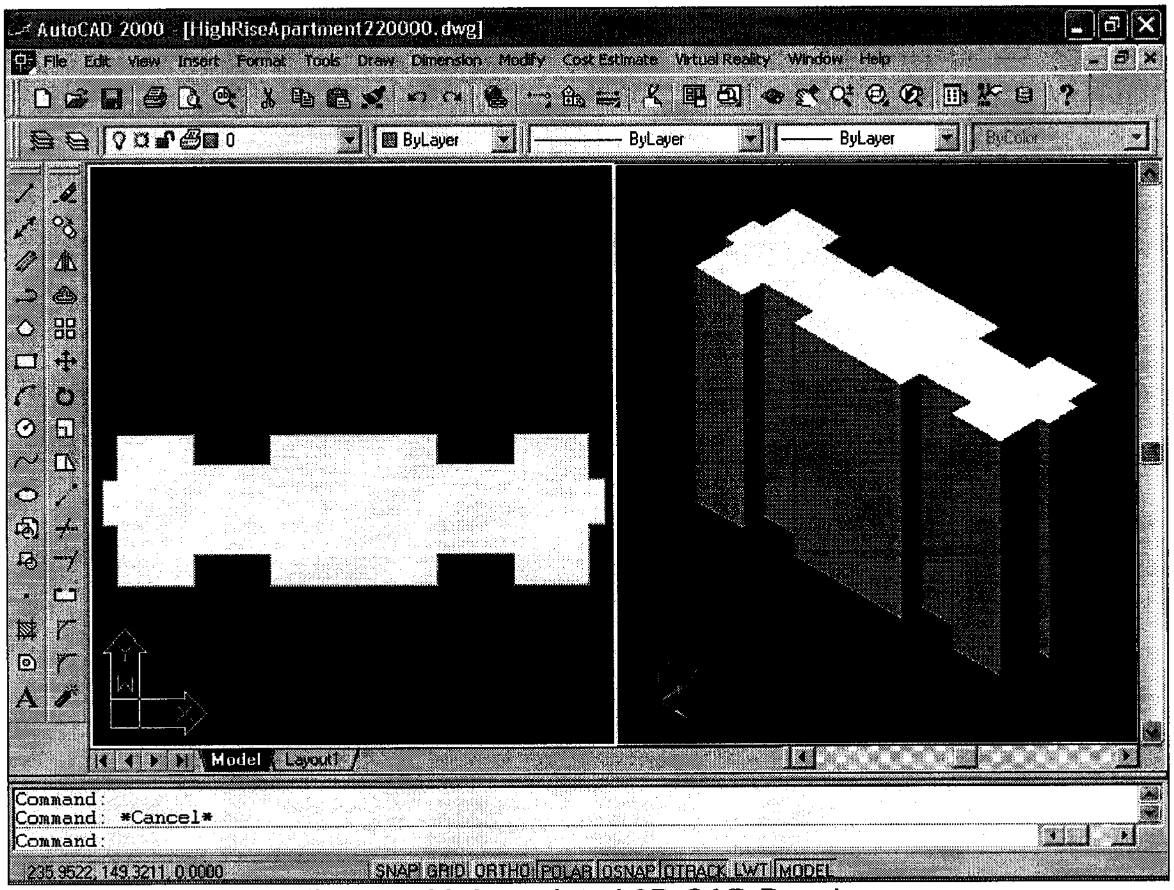


Figure 5.63 Associated 3D-CAD Drawing

Users can modify the drawing and extract new parameters, then adjust the costs per square feet for size, height, perimeter, inflation, and location, and accordingly forecast a new estimate. In this case, the system supplies users with four different formats to visualize the new estimate depending on the required level of details. The first three are similar to Figures 5.62, 5.43 and 5.44, while the fourth consists of a summary format for the old and new estimates as given in Figure 5.64. Afterward, users can forecast the running costs of the facility and identify the sensitive parameters. All these procedures have been explained in previous paragraphs besides the different format of output reports that the system provides users with.

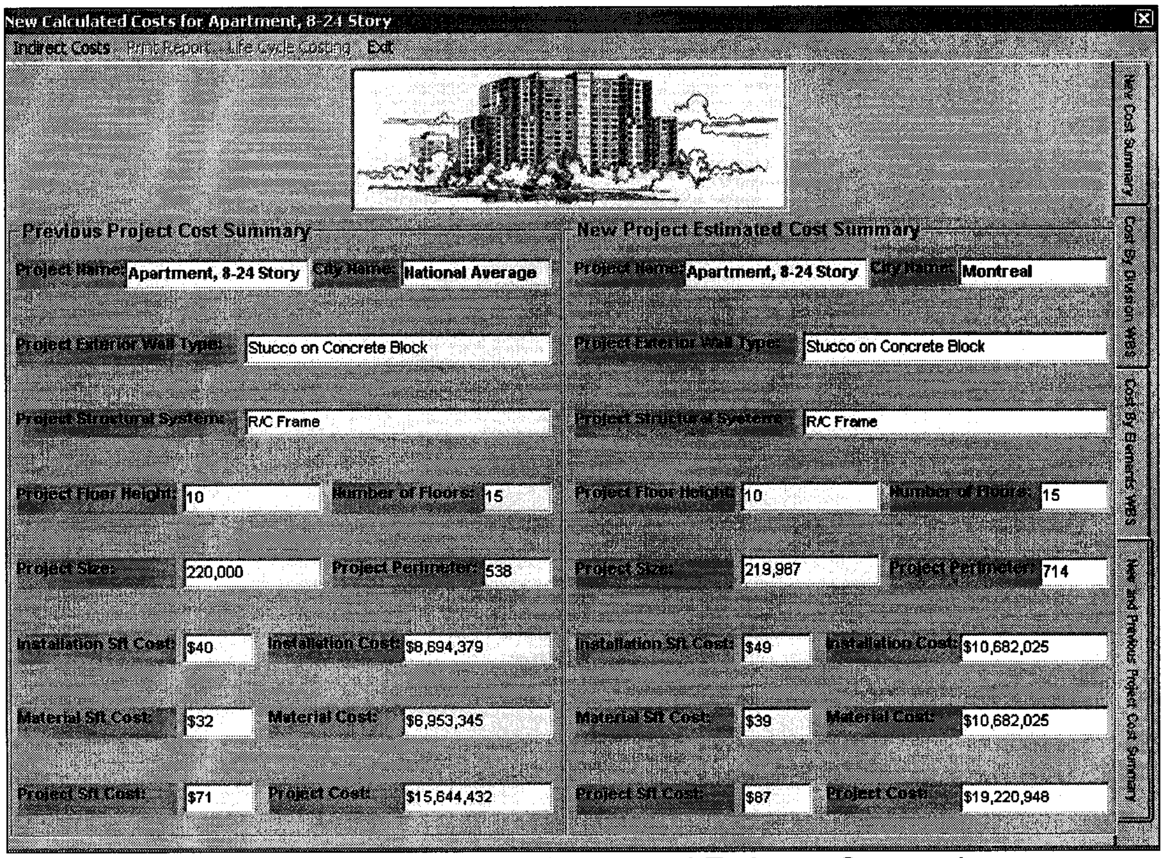


Figure 5.64 Old and New Forecasted Estimate Summaries

5.6.2 Sub-Module based on Budget Entry

The development of this sub-module differs from the previous one; however, its accessibility is similar in that the activation is done from the gateway form of phase (3) as shown in Figure 5.65. Nonetheless, when users click "Based on Budget Entry" the system instantly prompts them to enter the budget as illustrated in Figure 5.66. The system requests the user to confirm acceptance or rejection of the entered budget's value. If the value is accepted, the system requires them to identify the type of costs included in this budget as shown in Figure 5.67.

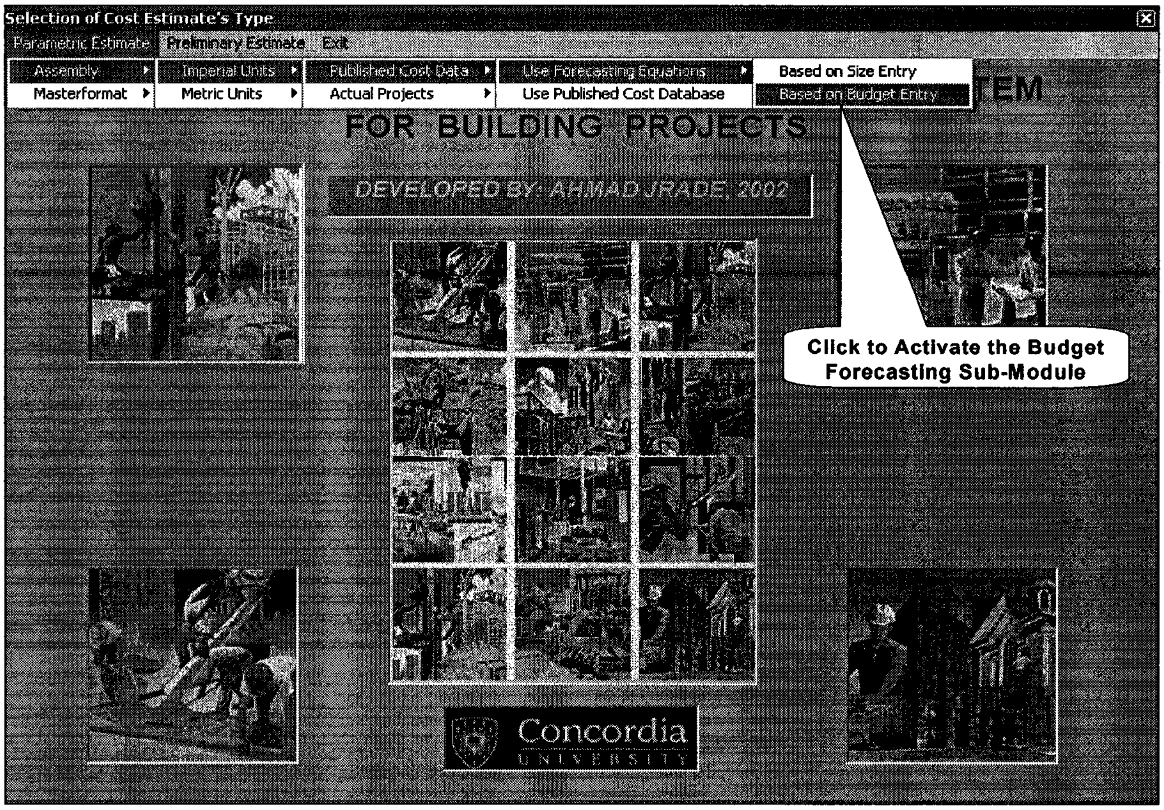


Figure 5.65 Accessing the Sub-Module from the Entryway of Phase (3)

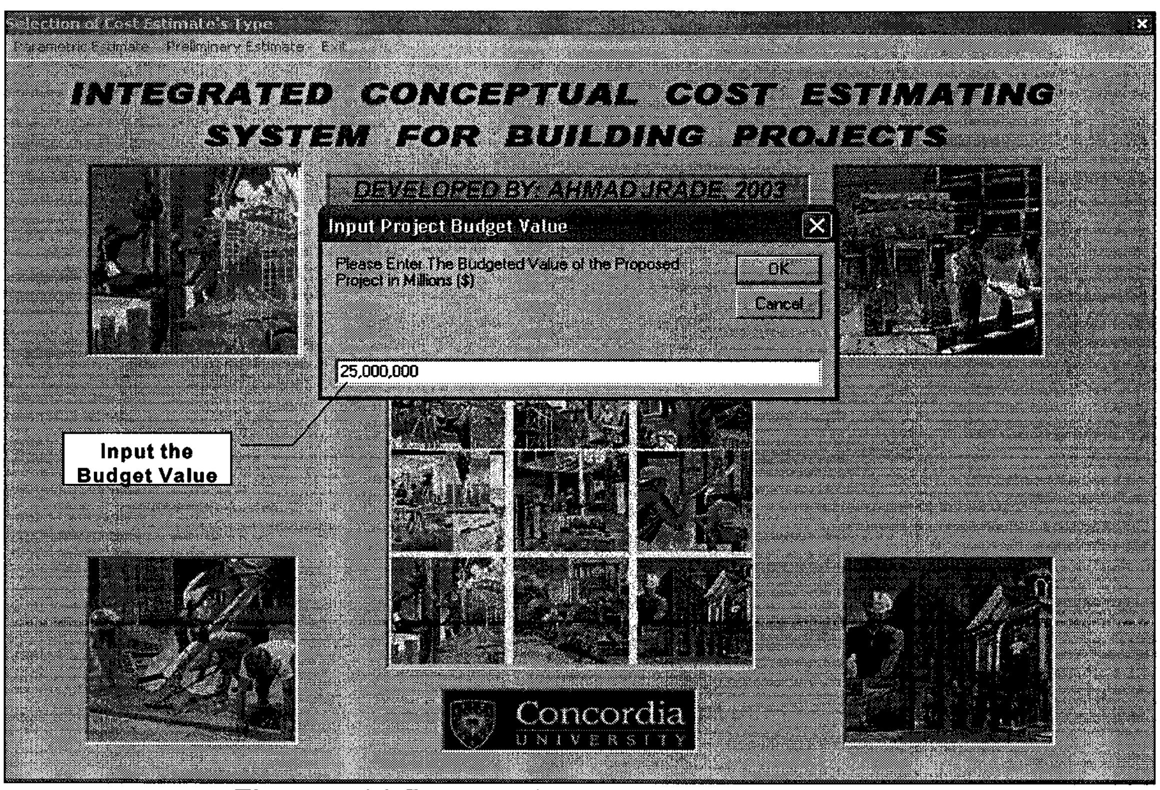


Figure 5.66 Proposed Project Budget Entry Form

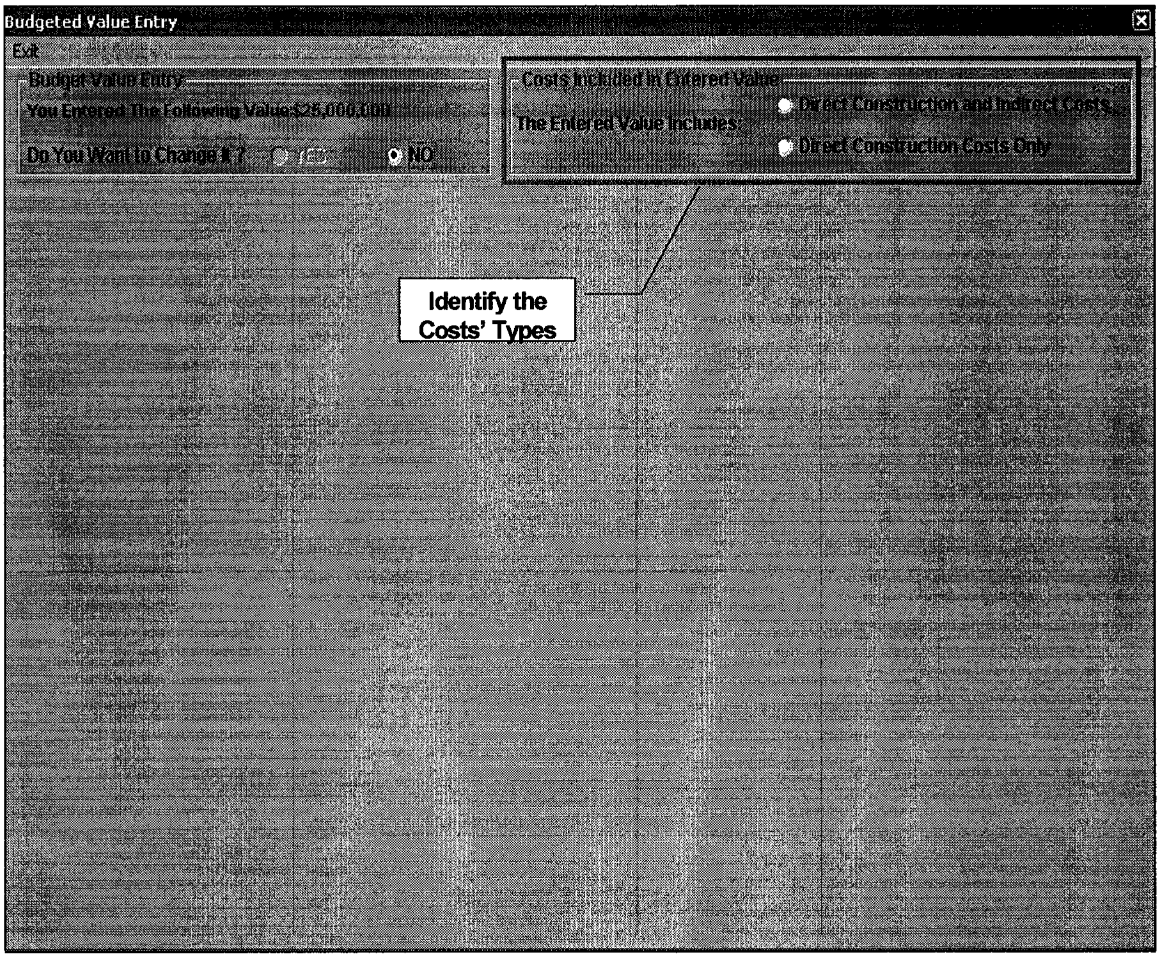


Figure 5.67 Identifying the Costs Included in the Budget

As soon as the cost type is identified, users are requested to input the indirect cost values as a percentage. Although defaulted values are inherited in the system, users can change them if needed as exhibited in Figure 5.68. Instantly the system breaks down the budget value based on the inputted indirect costs using the equations [4.17] to [4.19] derived in Chapter Four. The reason for doing so is to differentiate the direct construction costs from the indirect costs included in the budget value set by the user. This matter is exemplified in Figure 5.69 with the notice that these cost values originated in the current year.

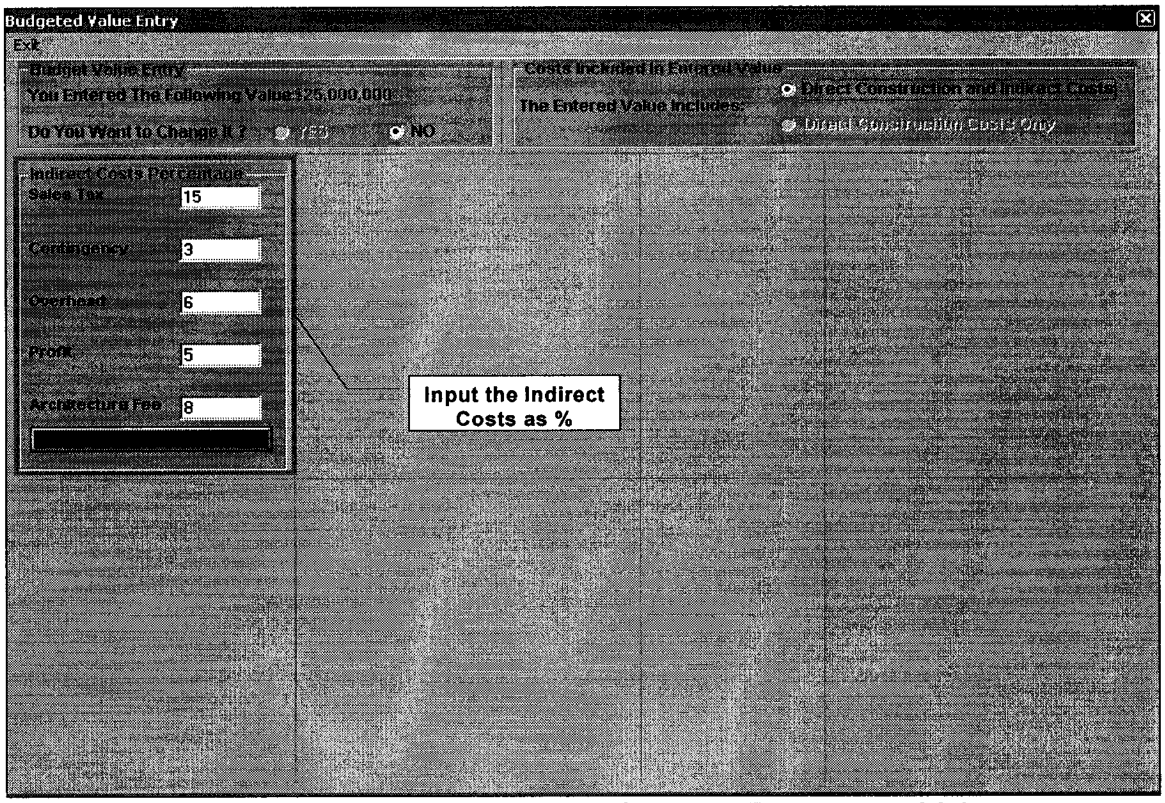


Figure 5.68 Entering the Indirect Costs as Percentage Values

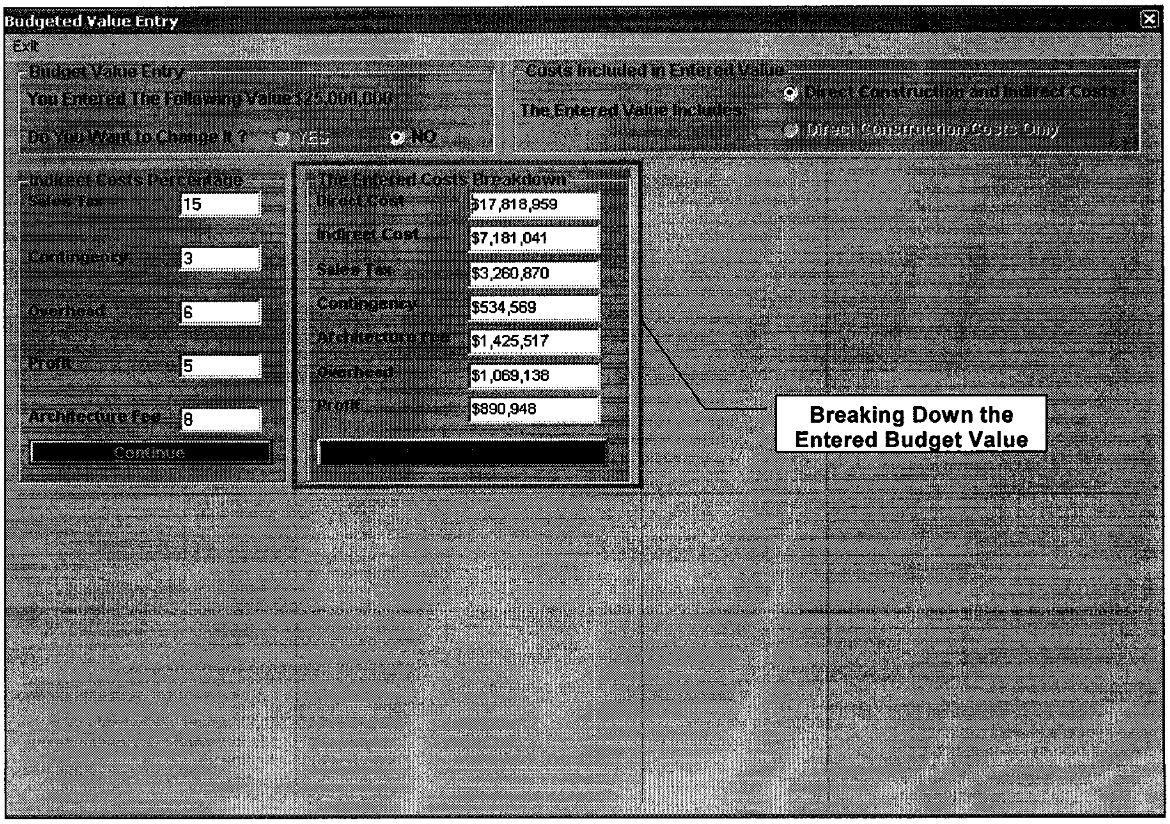


Figure 5.69 Breaking Down the Budget

After characterizing the budget cost's components, these components have to be brought to the national average costs using the equation [4.20]. For this reason, the system requires users to categorize the current city where the proposed project is located as shown in Figure 5.70. Following the city clarification, the system provides users with the default value of the city cost index for the selected Canadian city. Nevertheless, users can, if needed, still replace it with a new value as demonstrated in Figure 5.71.

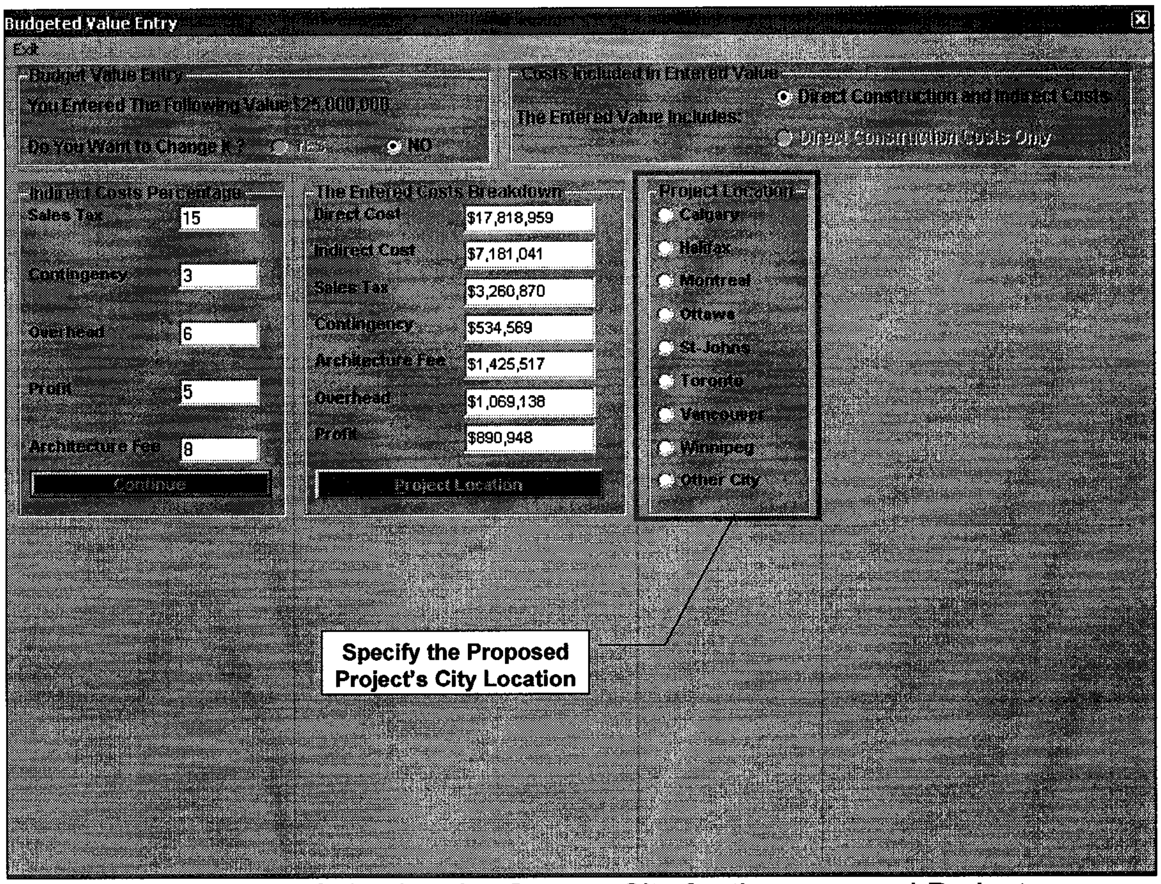


Figure 5.70 Selecting the Current City for the proposed Project

Afterward, the system brings all the broken values to the national average costs as exemplified in Figure 5.72. At this point, the system asks users to input the inflation rate in order to adjust and bring the national average values to year 2000

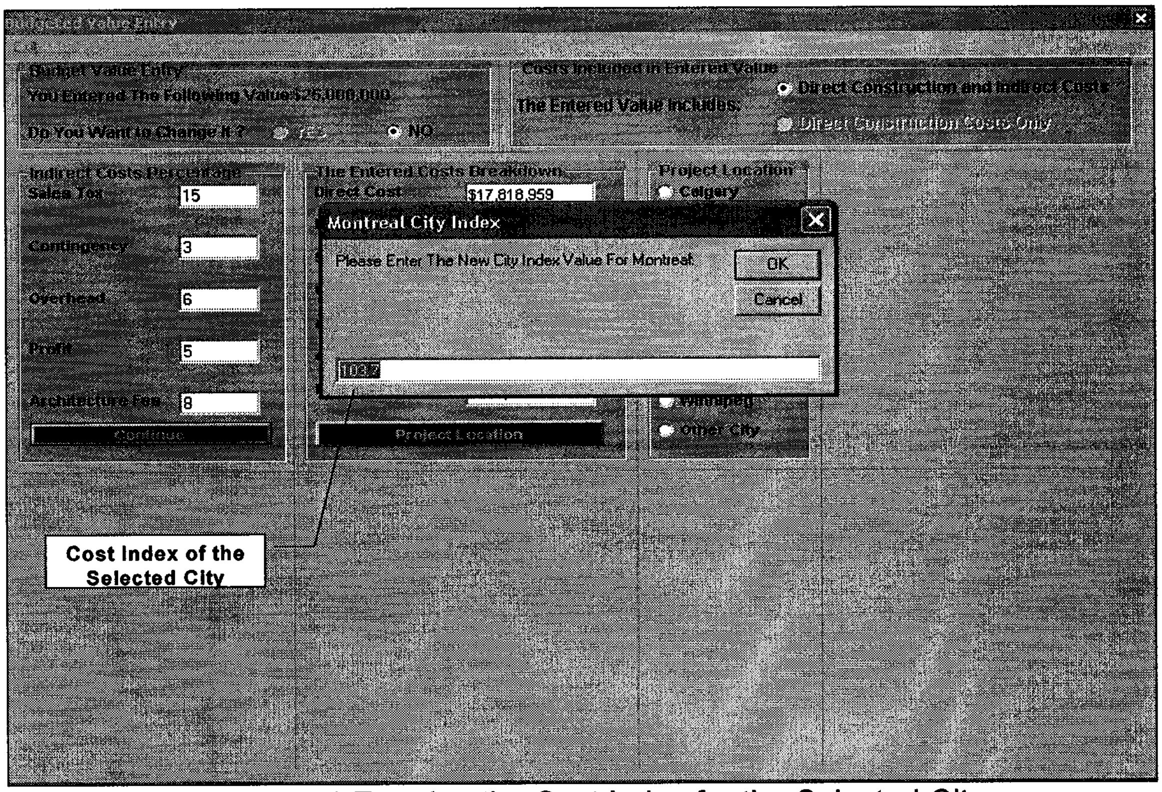


Figure 5.71 Entering the Cost Index for the Selected City

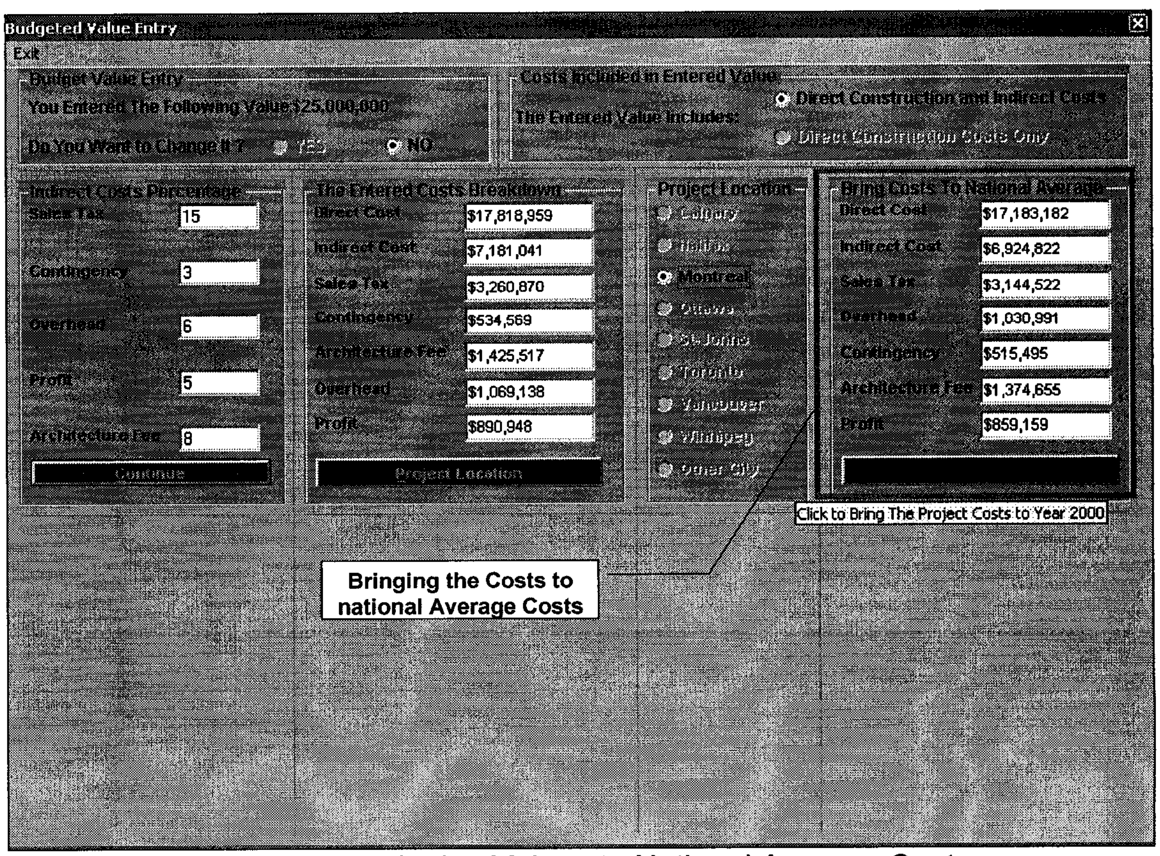


Figure 5.72 Bringing Values to National Average Costs

by using the equation [4.21]. It is to be noted that the system automatically computes the value of (n) and subsequently transports the values back to year 2000 instantaneously after users punch-in the inflation rate as Figure 5.73 shows.

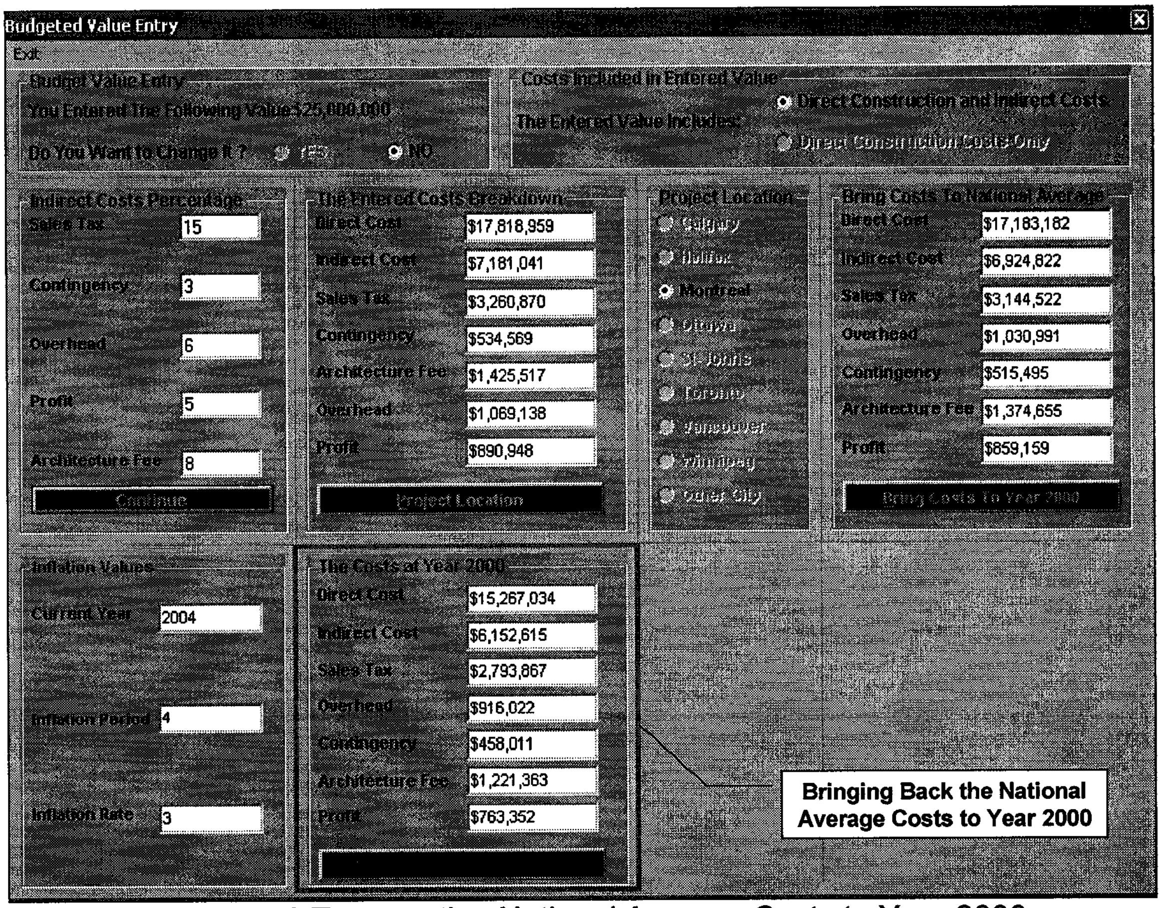


Figure 5.73 Transporting National Average Costs to Year 2000

The system needs to know the proposed project's category. Therefore, it requests users to select it from the provided list of options as shown in Figure 5.74. When the project's category is selected, the system provides users with options of either manually selecting the project type and associated exterior wall and framing types or letting the DSS to perform this operation for them as shown

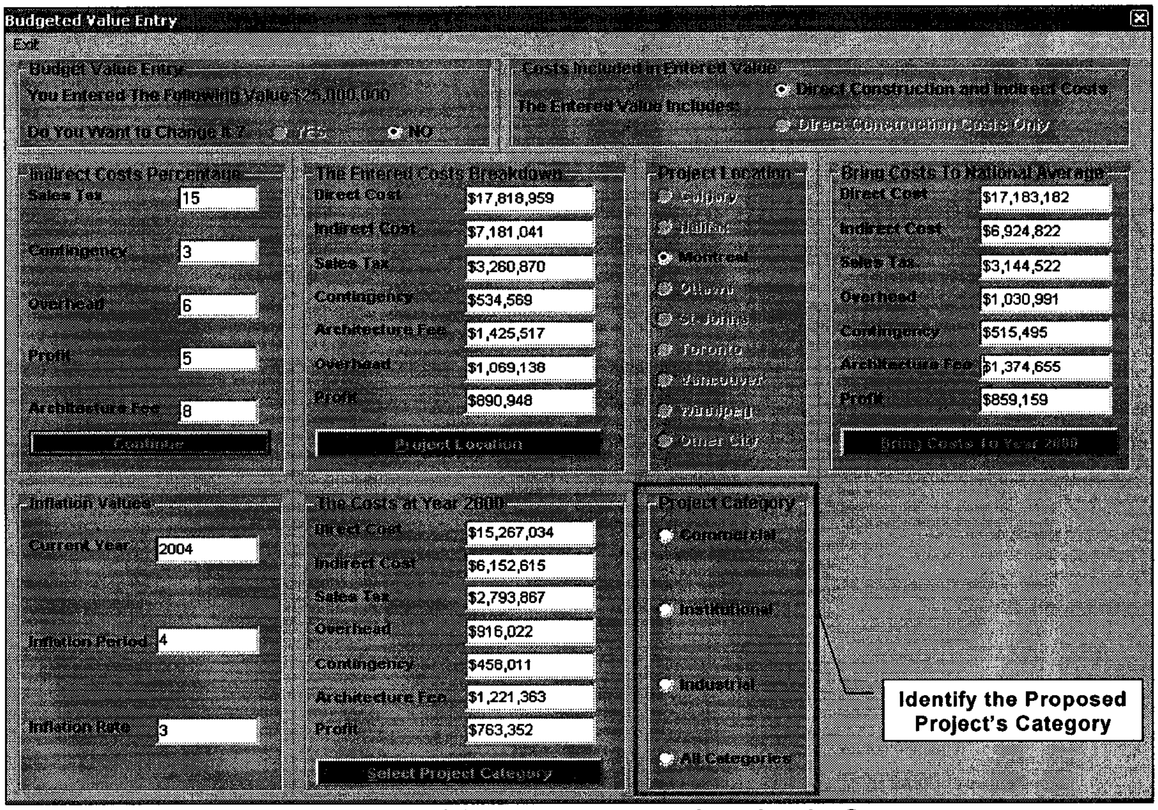


Figure 5.74 Identifying the Proposed project's Category

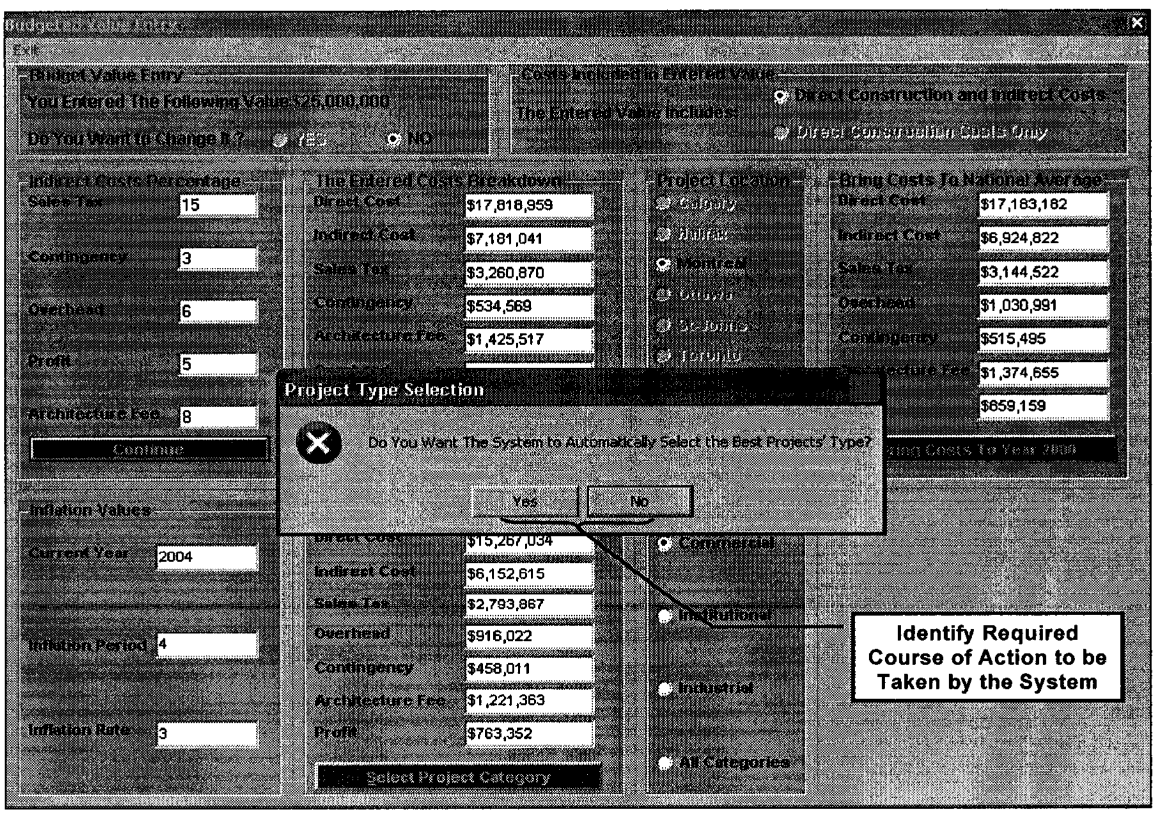


Figure 5.75 Course of Action Needed by Users

in Figure 5.75. If users click the "Yes" button, they opt for the DSS. The ensuing procedure is to be explained in detail in the paragraph 5.6.3. On the other hand, if the "No" button is clicked then the system necessitates users to choose the project's type as Figure 5.76 exhibits.

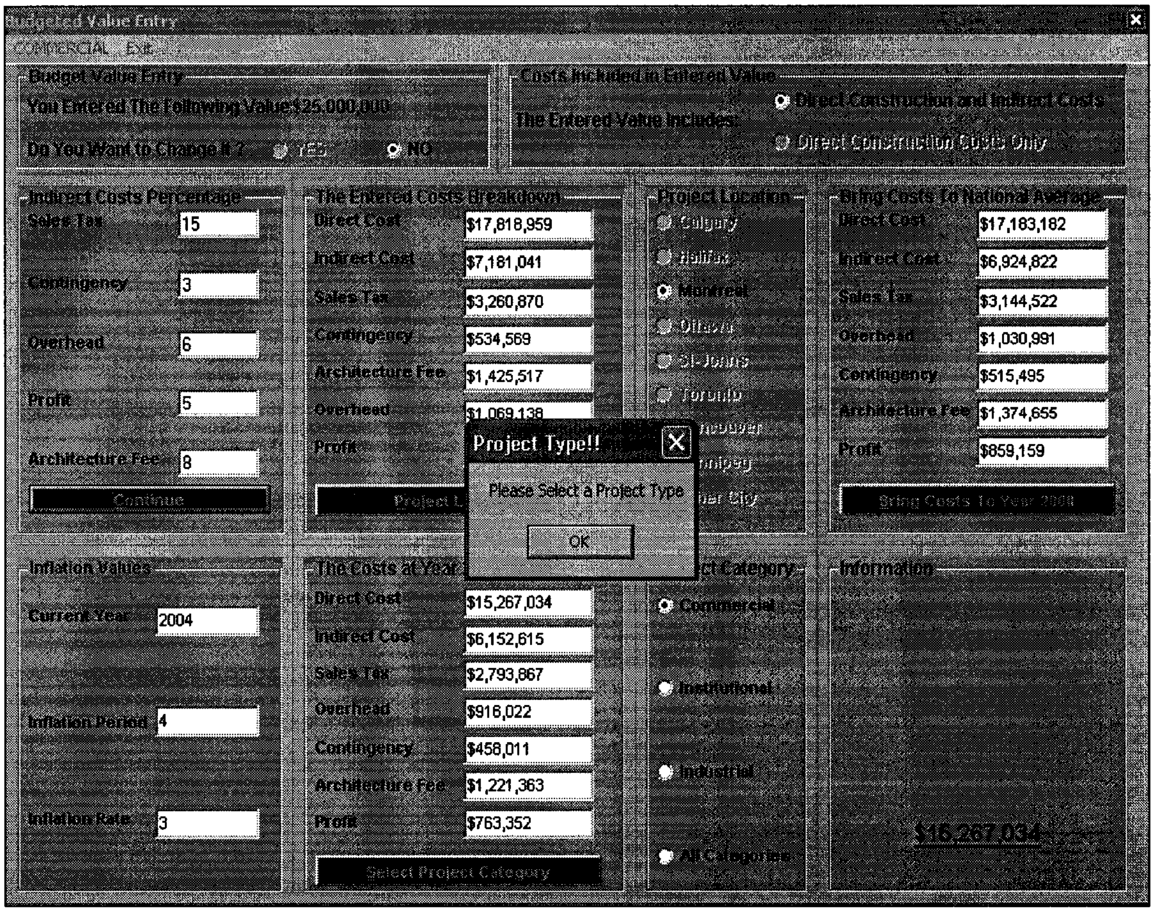


Figure 5.76 Selecting Project's Category

At the same time the "OK" button is clicked, the system activates a top menu associated with the chosen project's category so that users can make their choice of project type as shown in Figure 5.77. At once, after the project type choice is finished, the system requests users to make a combination of selections for the exterior wall and its related framing type as Figures 5.78 - 5.79 show. Yet the system forecasts the project's area using the equations mentioned

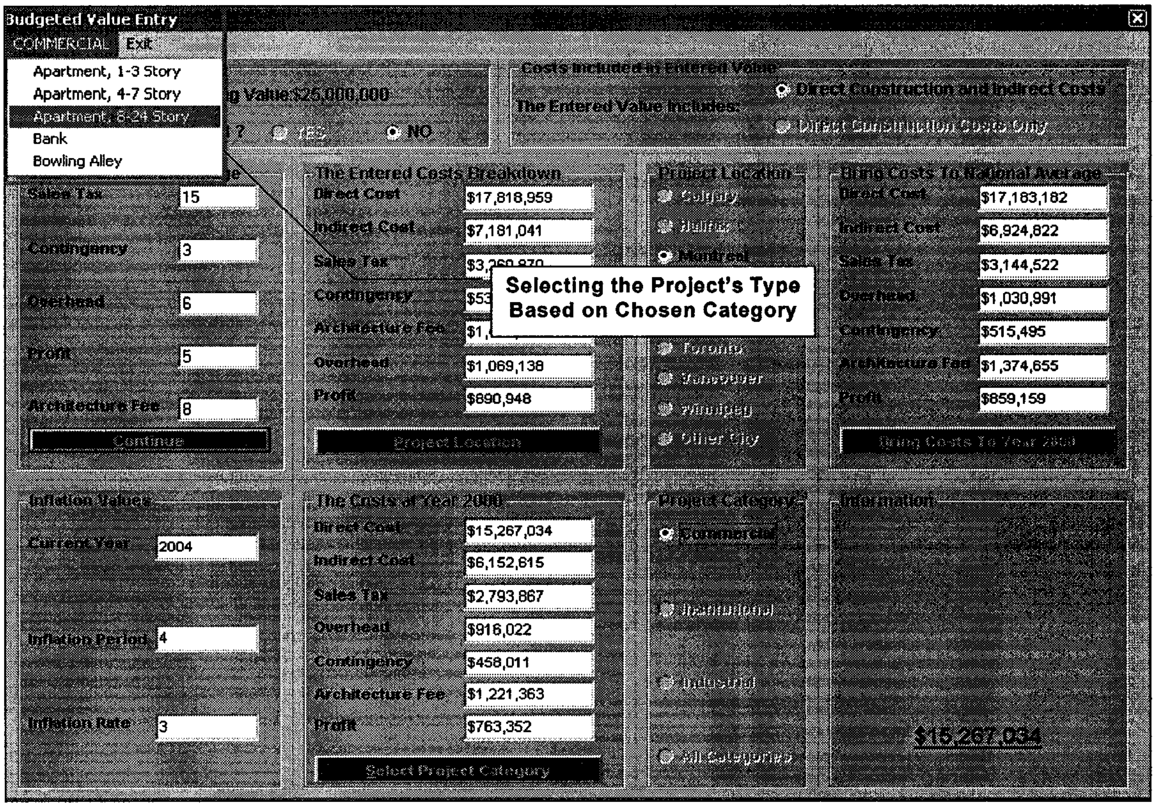


Figure 5.77 Choosing the Project's Type

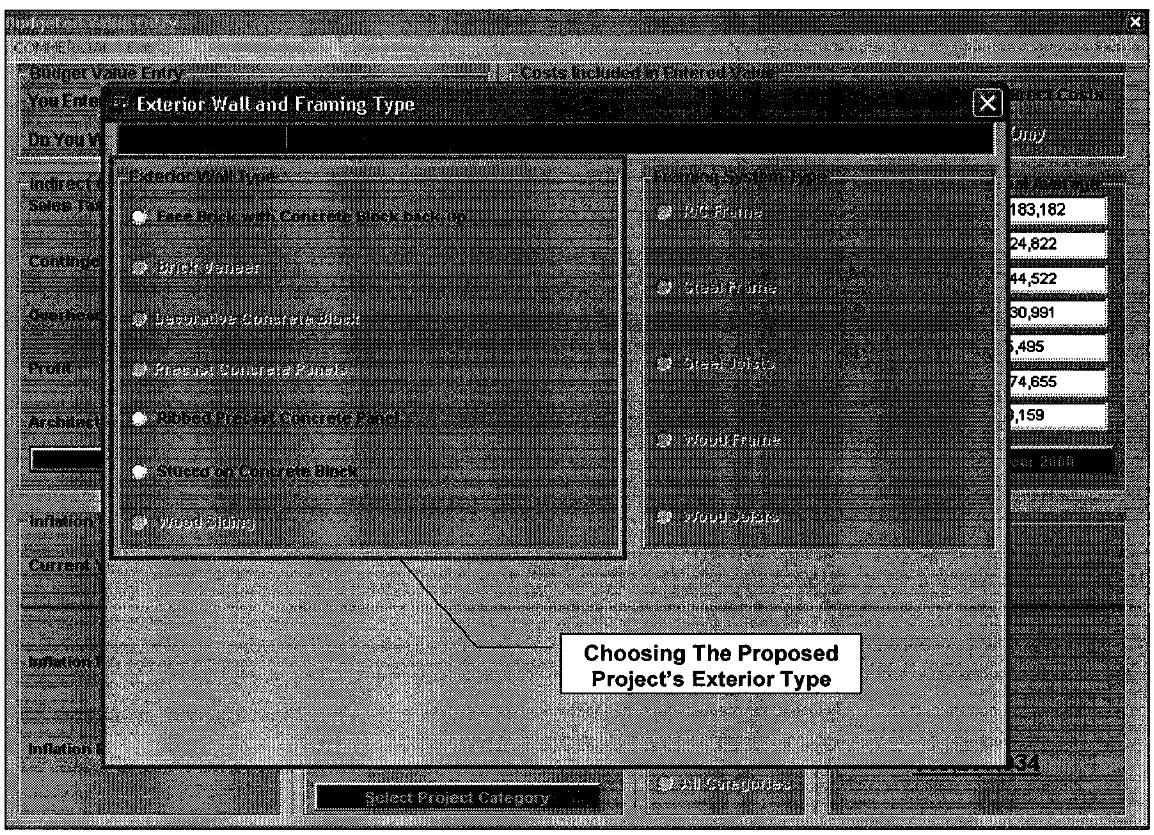


Figure 5.78 Identifying the Project's Exterior Wall Type

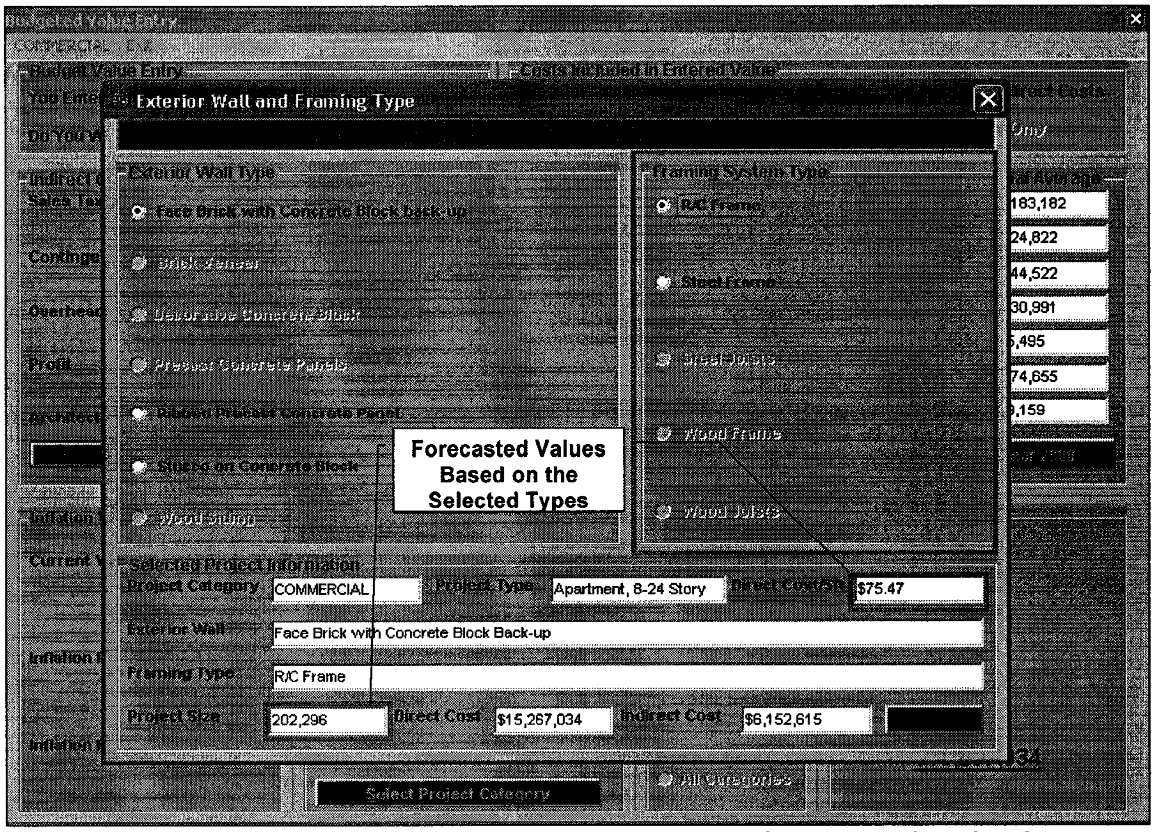


Figure 5.79 Selecting Associated Framing Type & Forecasting the Area

in paragraph 4.8.2 and Figure 4.24 of Chapter Four, and calculates the cost per square foot of the proposed project. Furthermore, the system forecasts the whole estimate routed on the forecasted area and direct construction costs computed from the entered budget. Three different levels of detail are provided by the system besides the possibility of visualizing the coupled 3D-CAD drawing for modification and accordingly forecasting the new estimate based on the extracted parameters from that drawing after necessary adjustments are executed. Figure 5.80 exemplifies one of the summarized formats supplied by the system. Certainly, users can forecast the running costs of the proposed project besides applying sensitivity analysis method in similar procedures as explained in preceding paragraphs. As such, the development of this sub-module

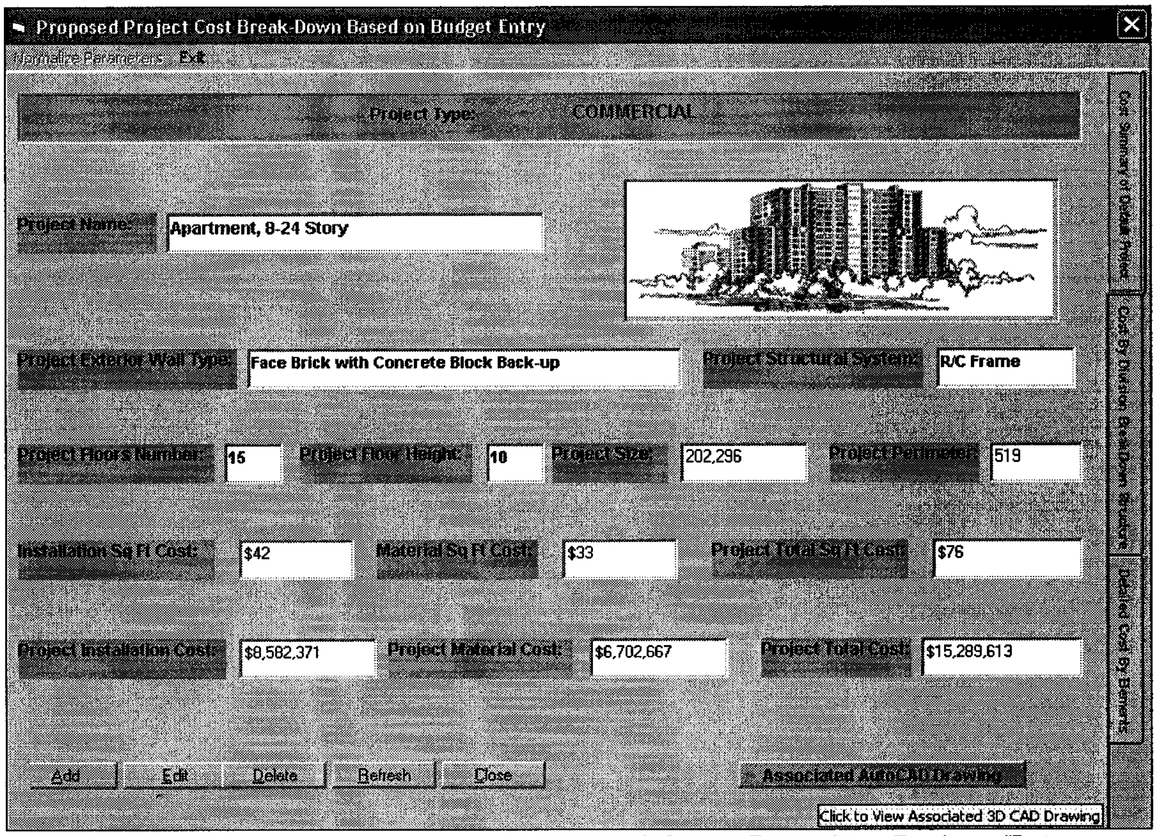


Figure 5.80 Summary of the Forecasted Costs Based on Budget Entry

would be accomplished.

5.6.3 Decision Support System's Sub-Module

As mentioned earlier this sub-module consists of developing a decision Support System that assists investors and management in selecting the optimal project and drawing so that its costs match the entered budget. After assigning a set of rules for it and dividing them into three different classes that are wide, intermediate, and narrow, the physical implementation is initiated. The same procedures followed in section 5.6.2 that are summarized in Figures 5.65 to 5.75 are carried out at the start of this sub-module. However, to run the DSS, users have to hit the "Yes" button as shown in Figure 5.81, directly after that the system calls for picking the desired set of rules to be applied as Figure 5.82 illustrates.

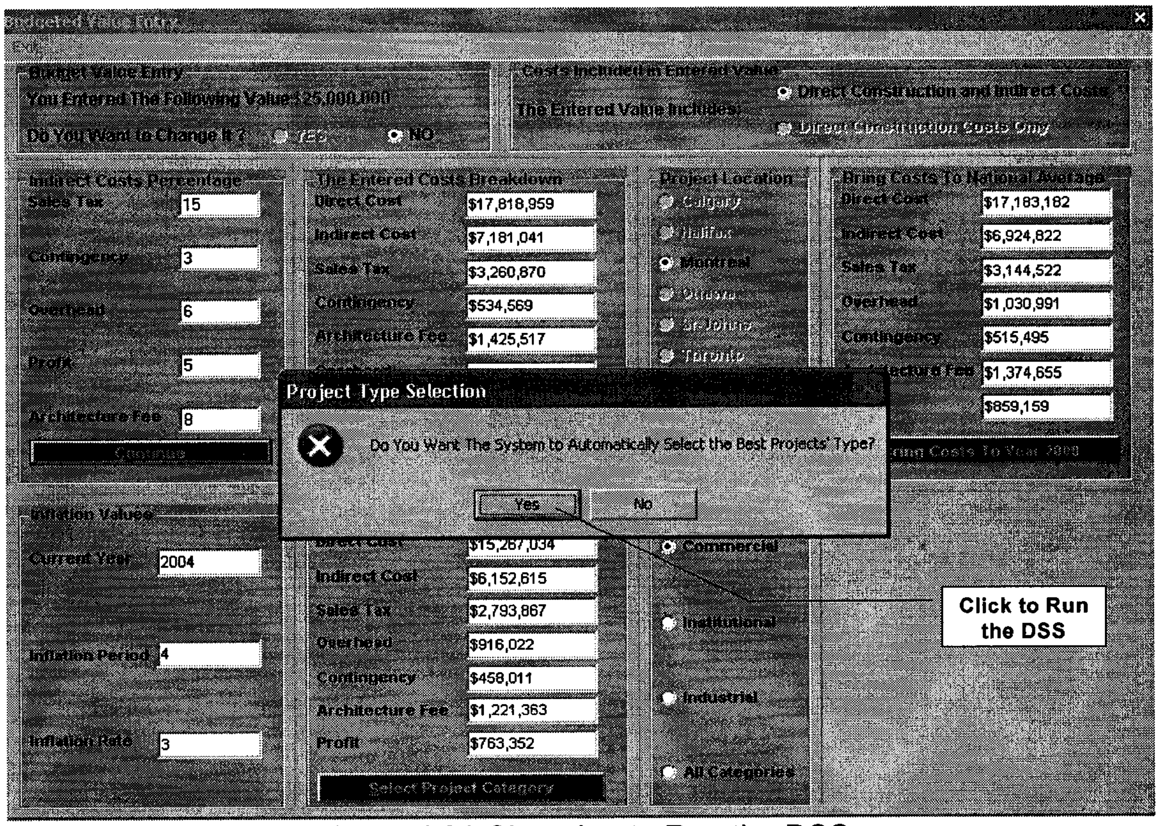


Figure 5.81 Choosing to Run the DSS

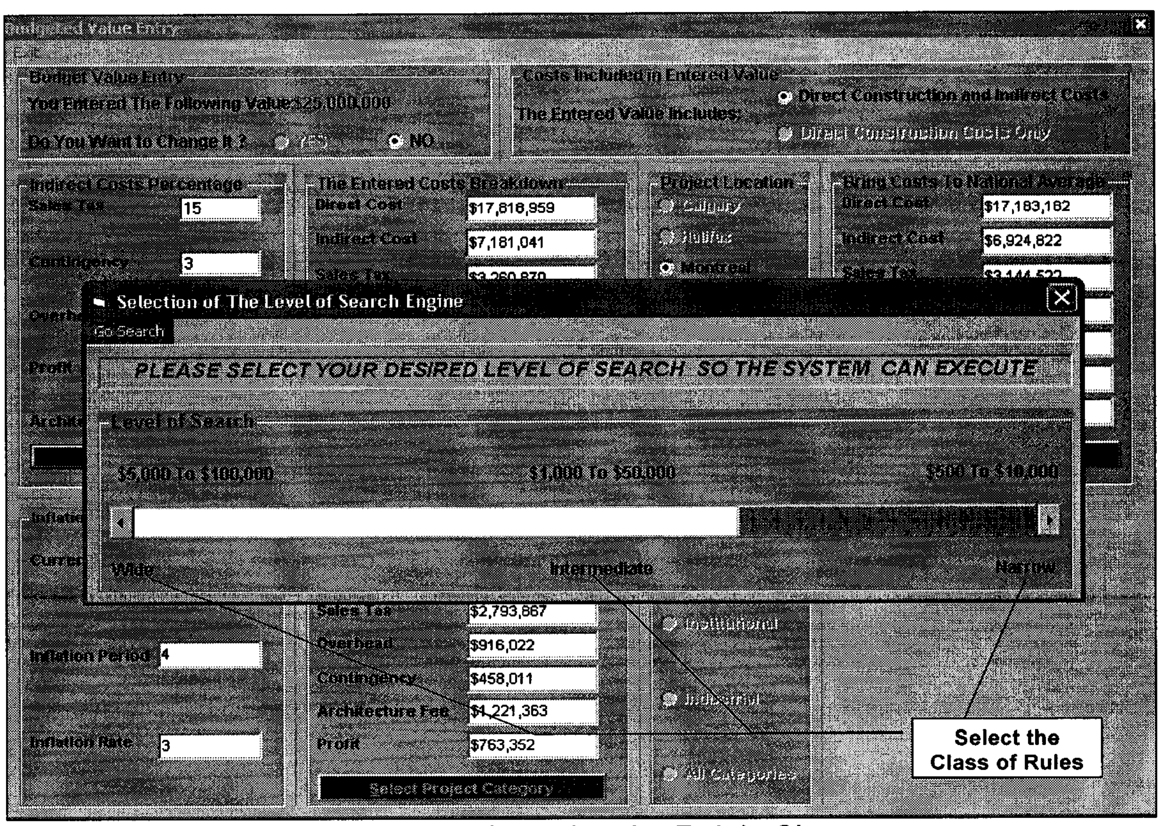


Figure 5.82 Selecting the Rule's Class

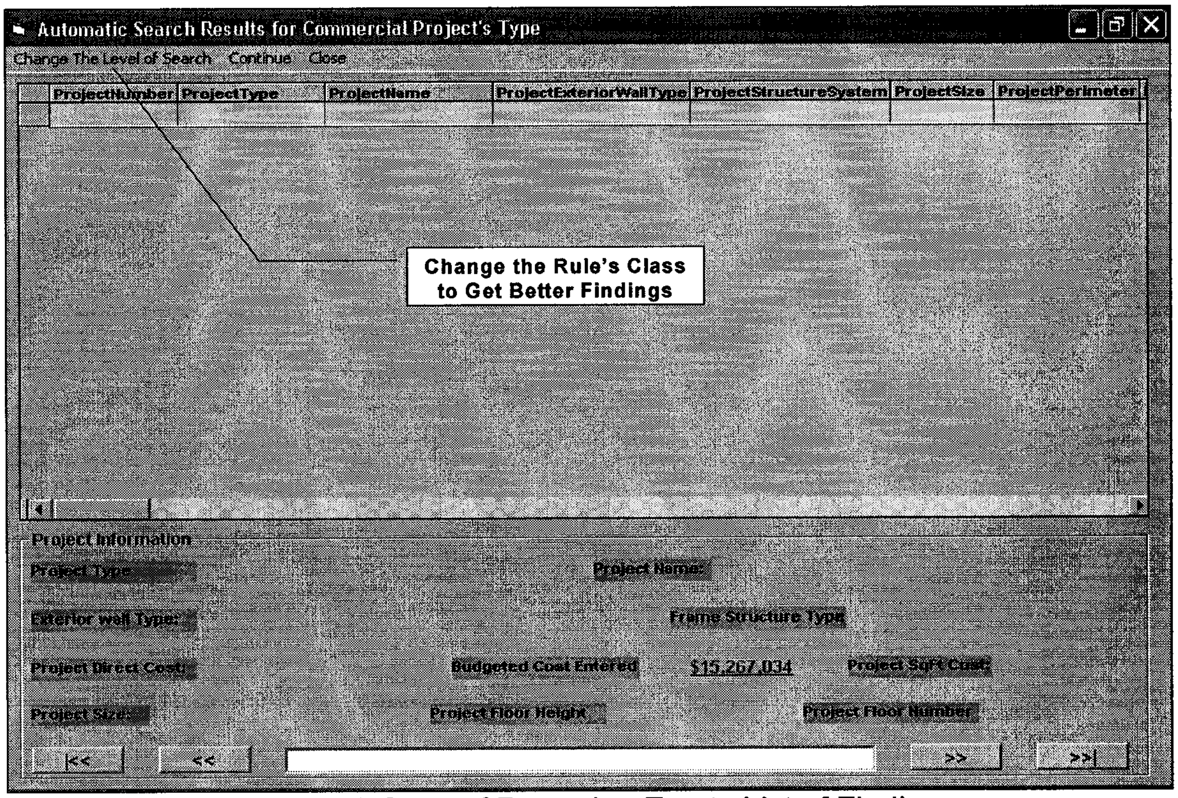


Figure 5.83 Case of Returning Empty List of Findings

If the DSS does not find a project that is compatible with the user's requirements, it returns an empty list of findings as shown in Figure 5.83. In this case, users have to change the class of rules (i.e., from Narrow to Intermediate or Wide), and run the DSS again as shown in Figure 5.84. The DSS provides users with a new list of findings based on the chosen class of rules as exemplified by Figure 5.85. Once users decide on the project the costs of which they want to forecast, the system immediately shows the forecasted area that matches the type, exterior wall and framing type of the chosen project as seen in Figure 5.86. Moreover, the system supplies three different formats for the forecasted costs similar to the ones explained in the preceding paragraphs. Additionally, users are provided with the option of asking the DSS to select the best 3D-CAD drawing with the total area close to the forecasted one.

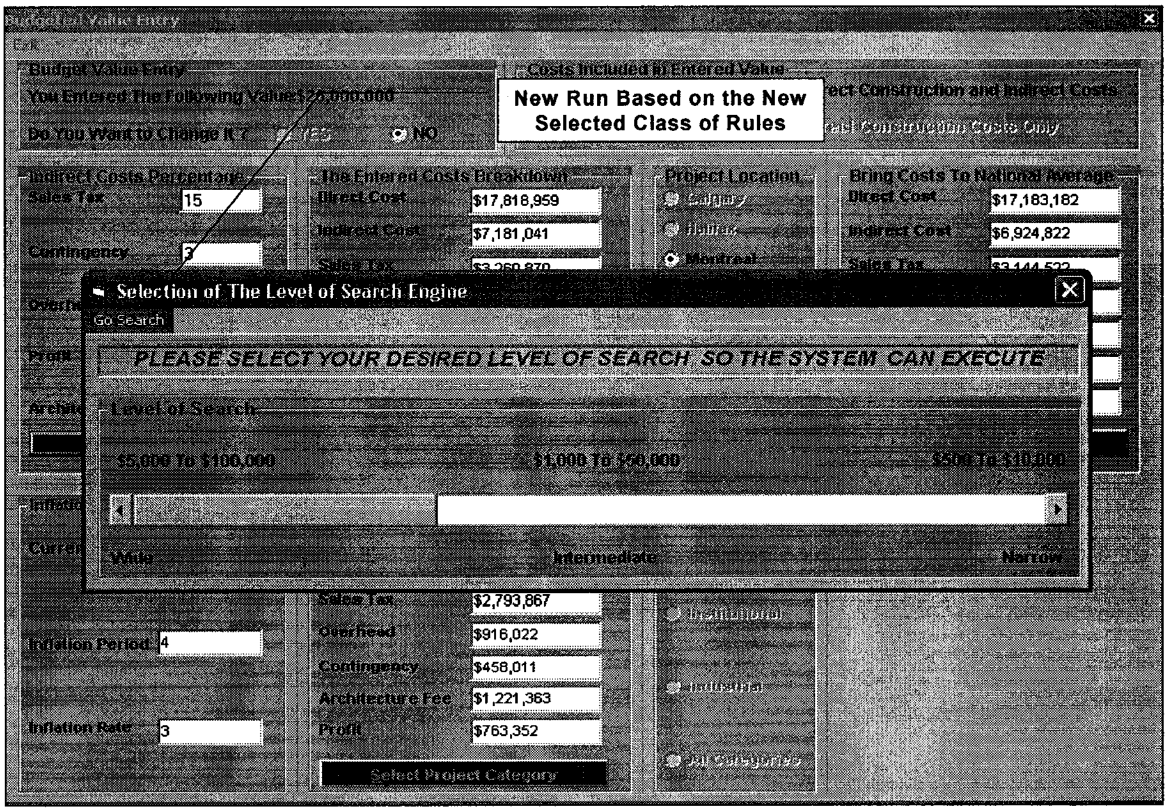


Figure 5.84 Changing the Rules' Class

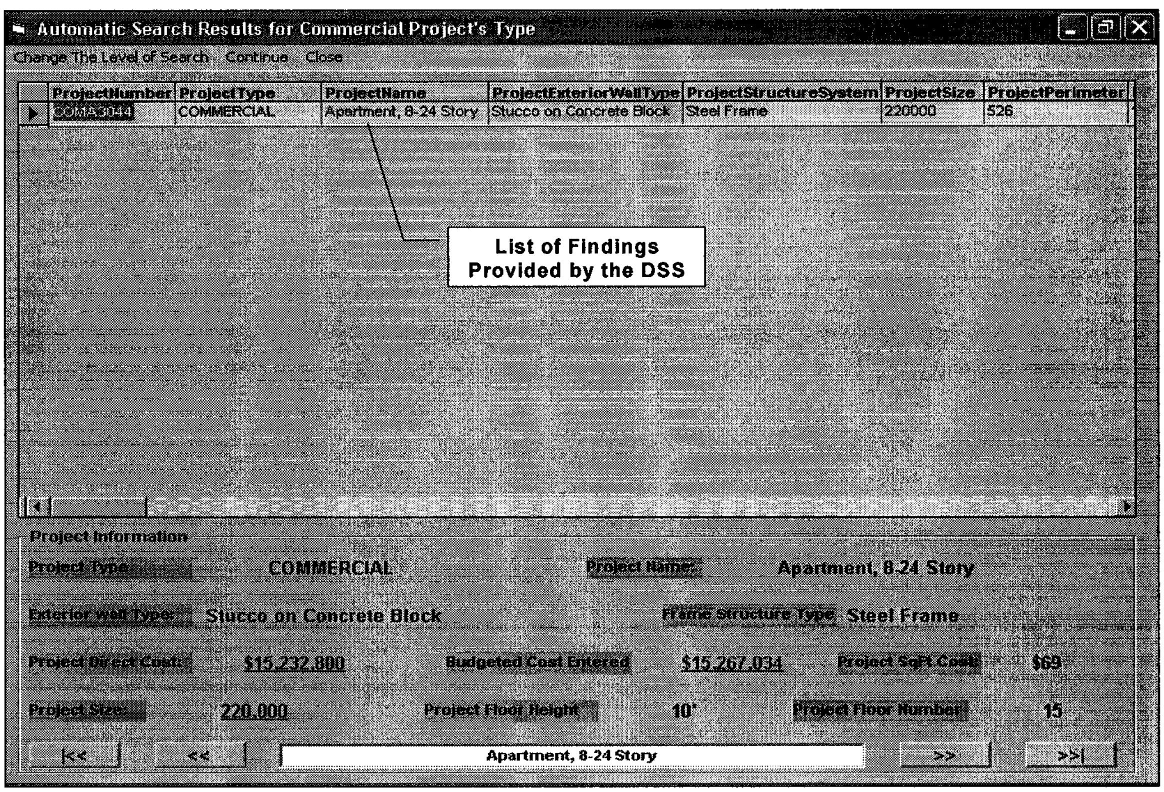


Figure 5.85 Optimum Project Selected by the DSS

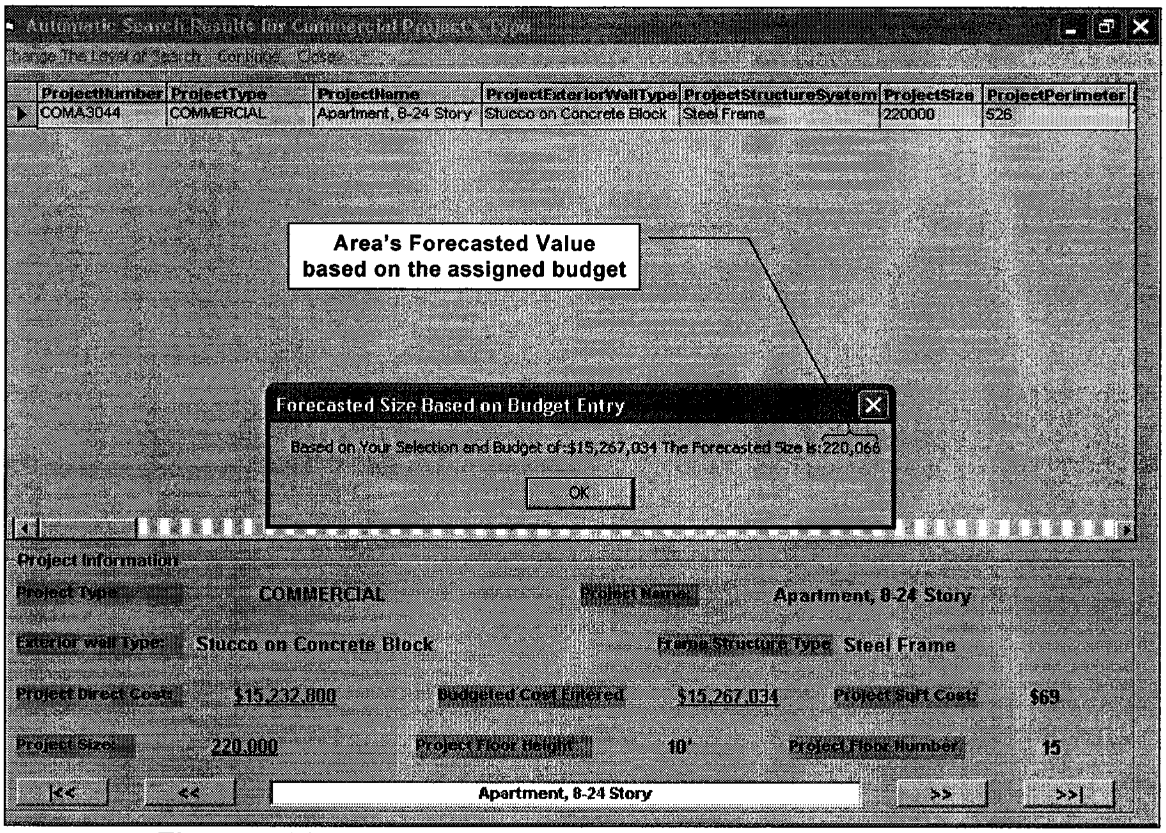


Figure 5.86 Forecasted Area Based on the Made Selections

This is achieved by clicking the “Associated AutoCAD Drawing” button as demonstrated in Figure 5.87. As a result the DSS opens the drawing as pictured in Figure 5.88. Needless to say, users can modify the drawing and consequently read and write the new parameters to the external database then adjust all the relevant costs based on these parameters and finally generate a new cost estimate after entering the indirect cost percentage values. Furthermore, users can still forecast the running costs of the proposed project and apply sensitivity analysis method as has been explained in previous paragraphs. Different format of output reports are generated by the system at the end of each of the third, fourth and fifth phases.

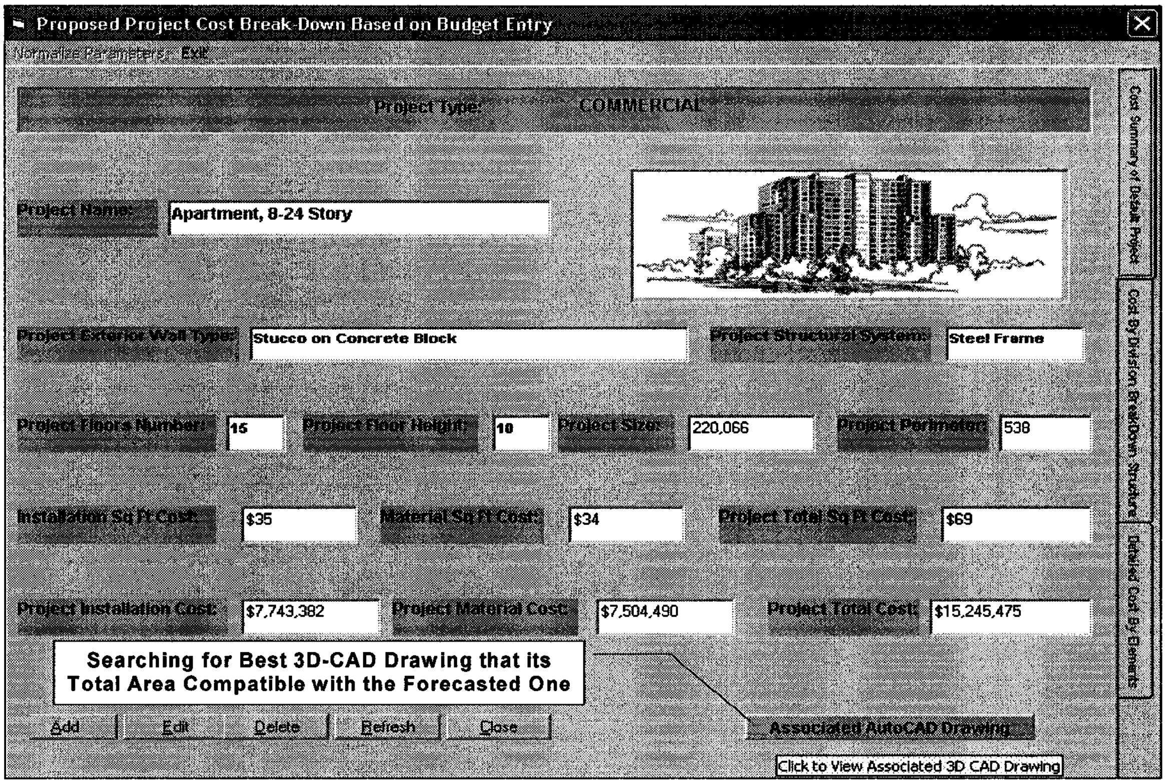


Figure 5.87 Running DSS to Select the 3D-CAD Drawing

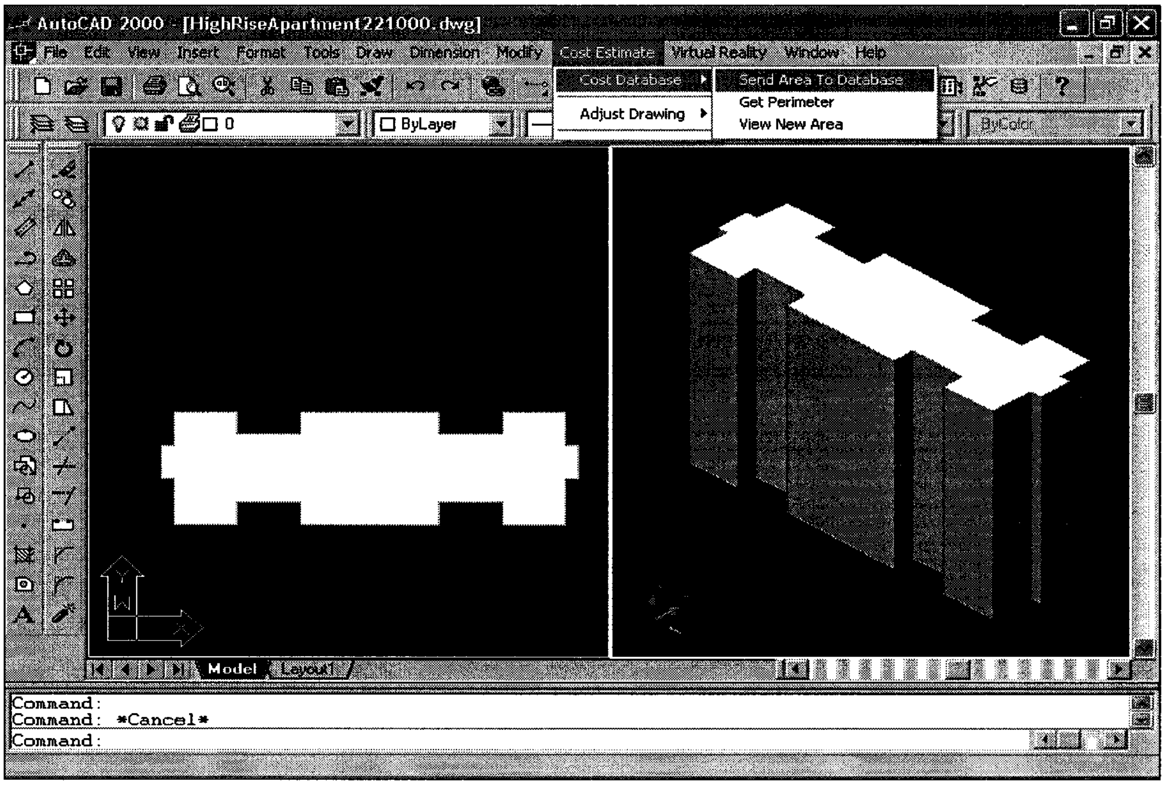


Figure 5.88 3D-CAD Drawing Selected by the DSS

5.7 Conclusion

This chapter has presented the physical development of the Integrated Conceptual Cost Estimating System for Building Projects, using Microsoft Access, Excel, and Visual Basic besides AutoCAD, 3D Studio, and Virtual Reality Browser. The development's design is accomplished in a way so that users are supplied with a variety of options by integrating many aspects of the estimating course of actions: starting with selecting the estimate type, choosing project similar to the proposed one, modifying its 3D CAD drawing, automating the retrieval of that drawing's parameters and writing them to an external database, forecasting the future cost and predictable income of the proposed facility, and applying sensitivity analysis method to identify sensitive parameters. Besides enhancing the system by a DSS that aids users in selecting the optimal project type and drawing routed on the limited budget provided by users. All these procedures are executed quickly and accurately so that anticipated errors are minimized thereby allowing users to manipulate the proposed project and accordingly its estimated costs instantly. Additionally, the system furnishes users with the option of selecting different types of professional output reports at the end of each phase of the system. These can be either tabulated or graphical. All the undertaken processes have been described and supported by figures and tables. Testing the system on an unseen project example showed its capability of analyzing user input and generating required output. On the other hand, in Chapter Six, an actual project is going to be used to examine the system's performance.

CHAPTER SIX

SYSTEM PERFORMANCE

6.1 Introduction

The preceding two chapters explored in detail the methodology and development methods followed in the proposed system within its modularity components. This chapter demonstrates the capabilities of the system with regard to its five modules: 1) Cost databases Module; 2) AutoCAD Module; 3) Global VB Module; 4) Life Cycle Costing and Sensitivity Analysis Module; and 5) Forecasting and Decision Support System Module. The performance of the system is examined through an actual high-rise building project constructed in Vancouver, British Columbia, Canada, by an owner-developer firm. The project consists of 80 units and has a Ribbed Precast Concrete Panel as exterior wall type and Steel Frame as structural framing type. Furthermore, it has a gross area of 129,095 ft^2 and its construction was completed in year 1996 for a cost of $10,254,326. The total project costs were $23, 029,641. Included in these costs is the cost of land that had a value of $5,042,964 (Appendix D shows the actual costs of that project). The system's capabilities and performance are measured using the three developed estimating tools, which are the database, forecasting equations based on size entry, and forecasting equations based on budget entry (by using the decision support system and manual selection).

6.2 Estimating Using Database

Since all the cost data used in the system are based on the National Average costs for year 2000, it is necessary to update the project direct construction cost from 1996 to 2000. Thus, the equation [4.10] is going to be used with an inflation rate of 3%. This makes the actual project's construction costs at year 2000 amount to $11,541,334. Next, applying the estimating tool using the database, a project type of high-rise building that has an area close to 129,095 ft^2 is selected from the database. The process starts by selecting the estimating tool to be used from the main form as shown in Figure 6.1.

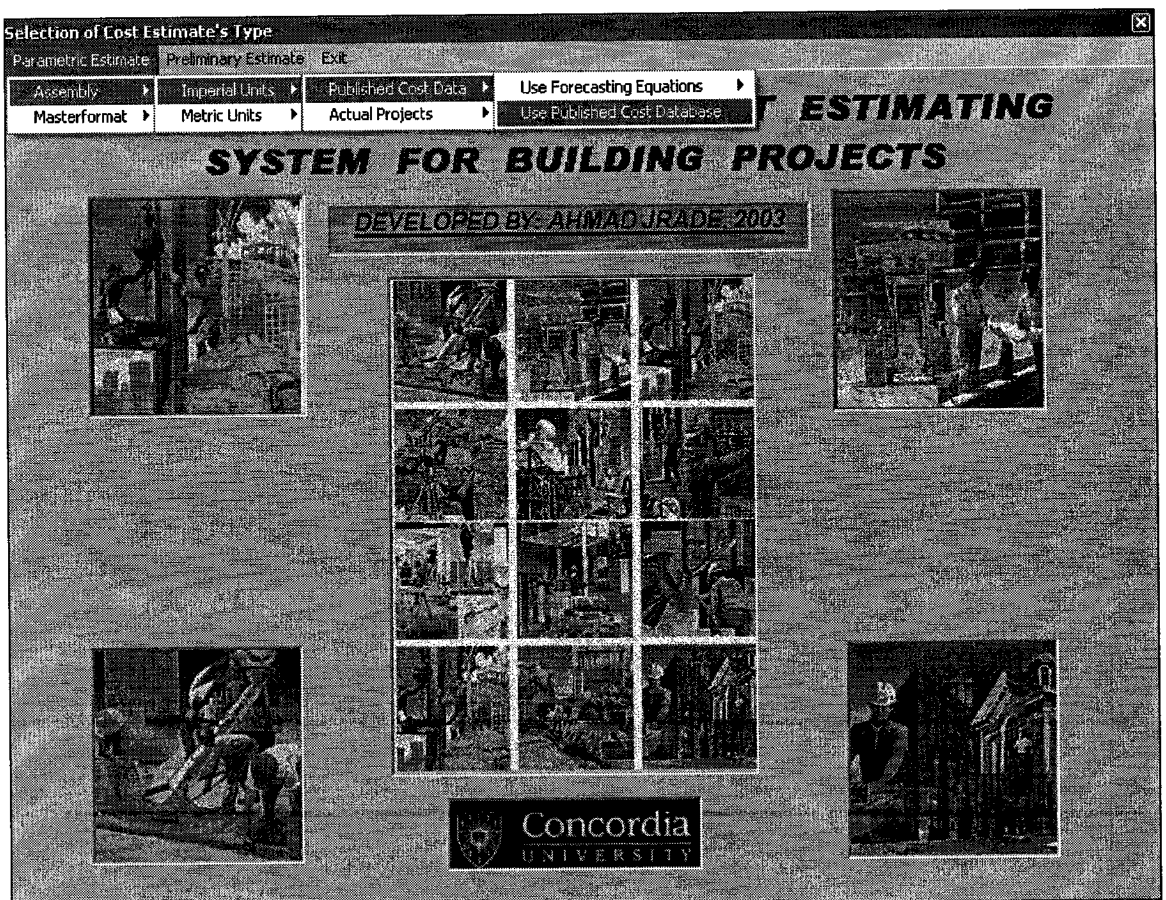


Figure 6.1 Selecting the Estimating Tool

Afterwards, one selects the project type, which is "Apartment, 8-24 Story" as given in Figure 6.2. The system also asks for the selection of the combination of area, exterior wall type, and framing system type.

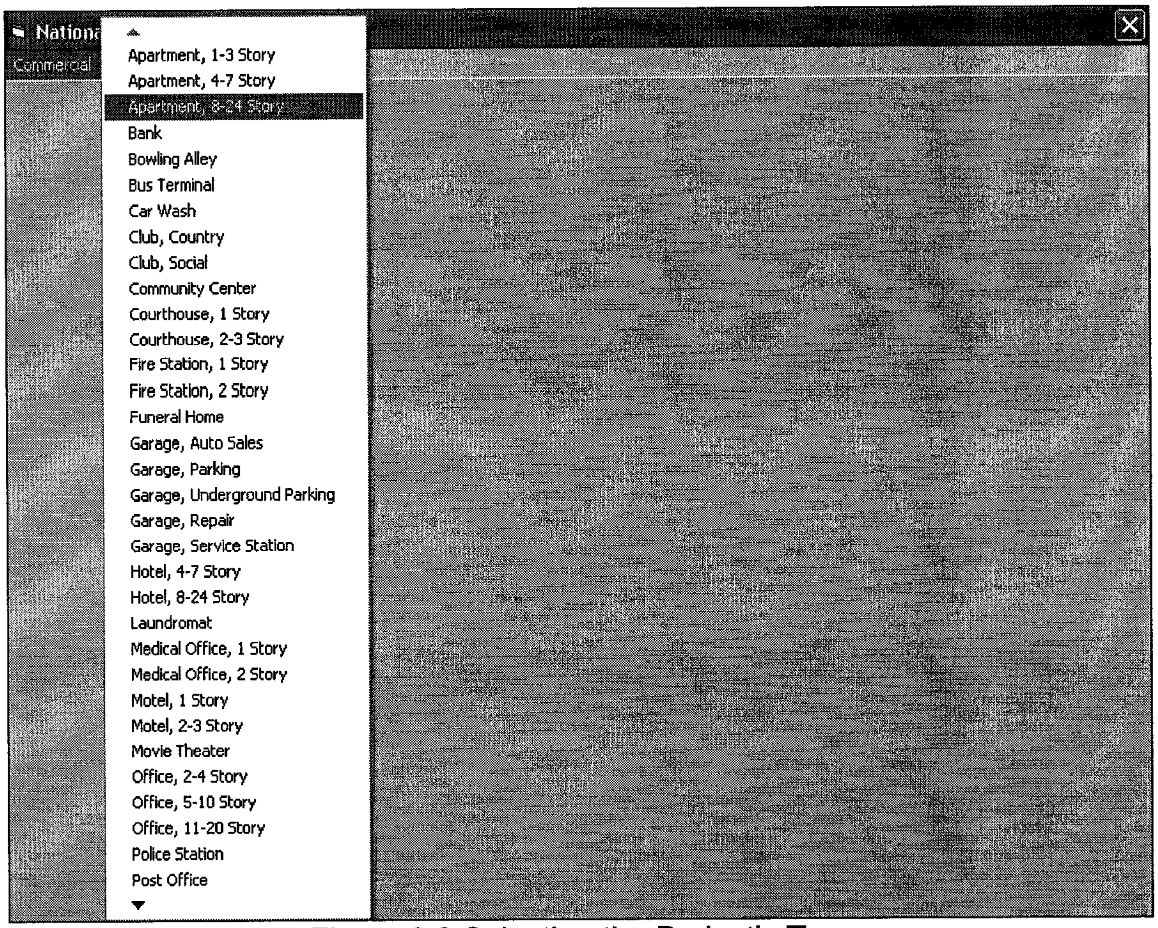


Figure 6.2 Selecting the Project's Type

At this stage, the selected parameters that are compatible with the actual project are the following: 129,000 ft^2, Ribbed Precast Concrete Panels and Steel Frame respectively as shown in Figures 6.3 to 6.5. Based on this selection the system contacts the database and queries the cost data related to the entered parameters. It accordingly retrieves and provides the information in three different formats that are summarized, detailed by divisions, and detailed by elements as demonstrated in Figures 6.6 to 6.8.

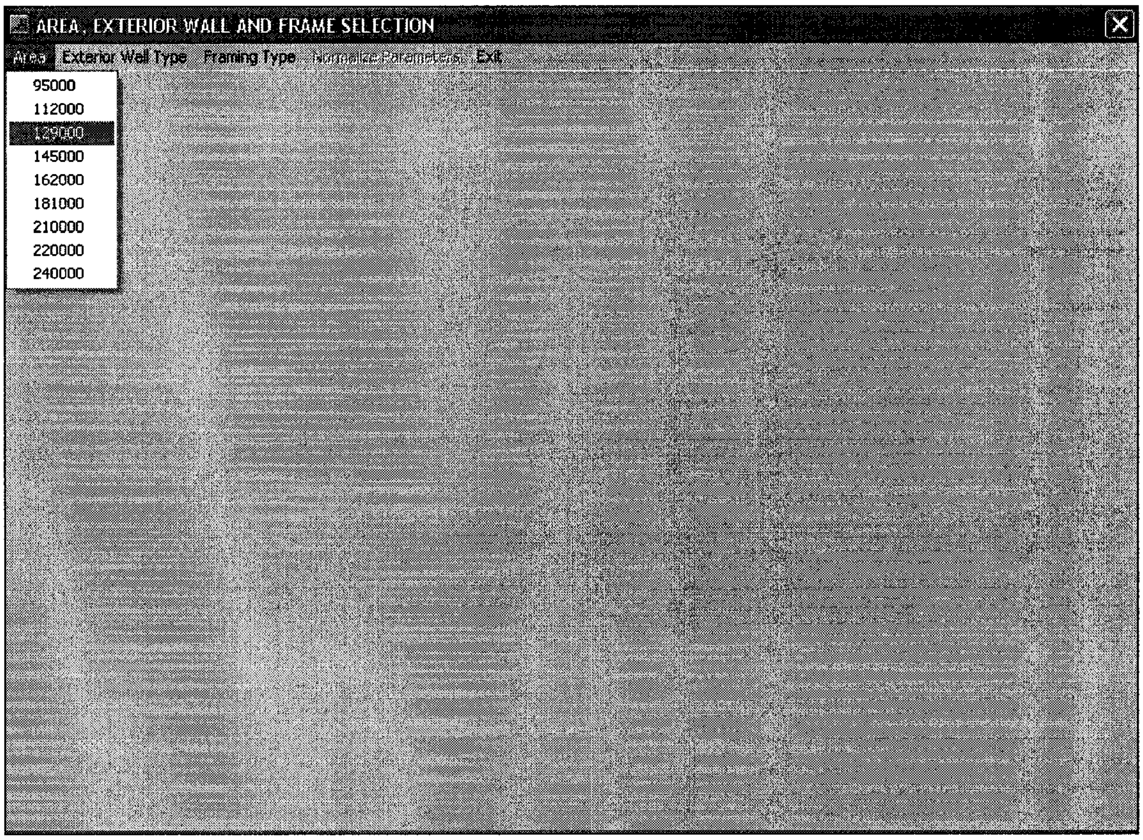


Figure 6.3 Selecting the Project's Area

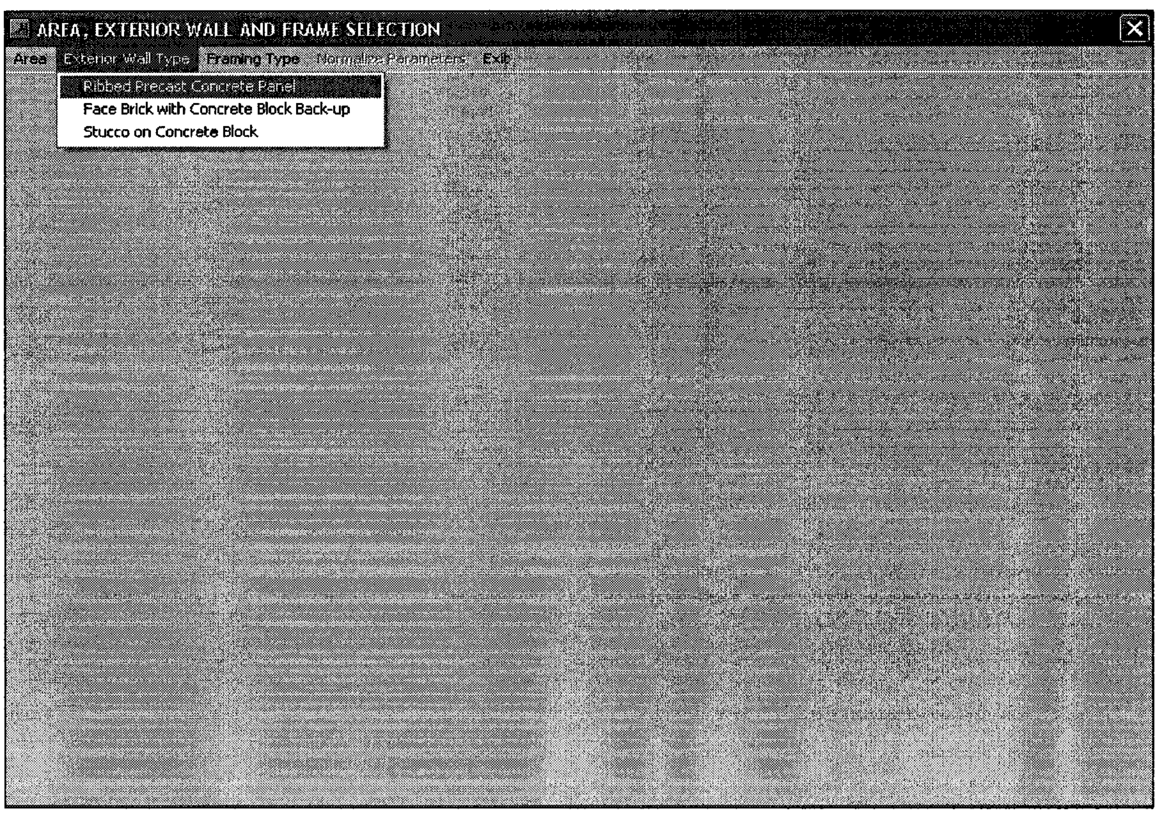


Figure 6.4 Selecting the Project's Exterior Wall Type

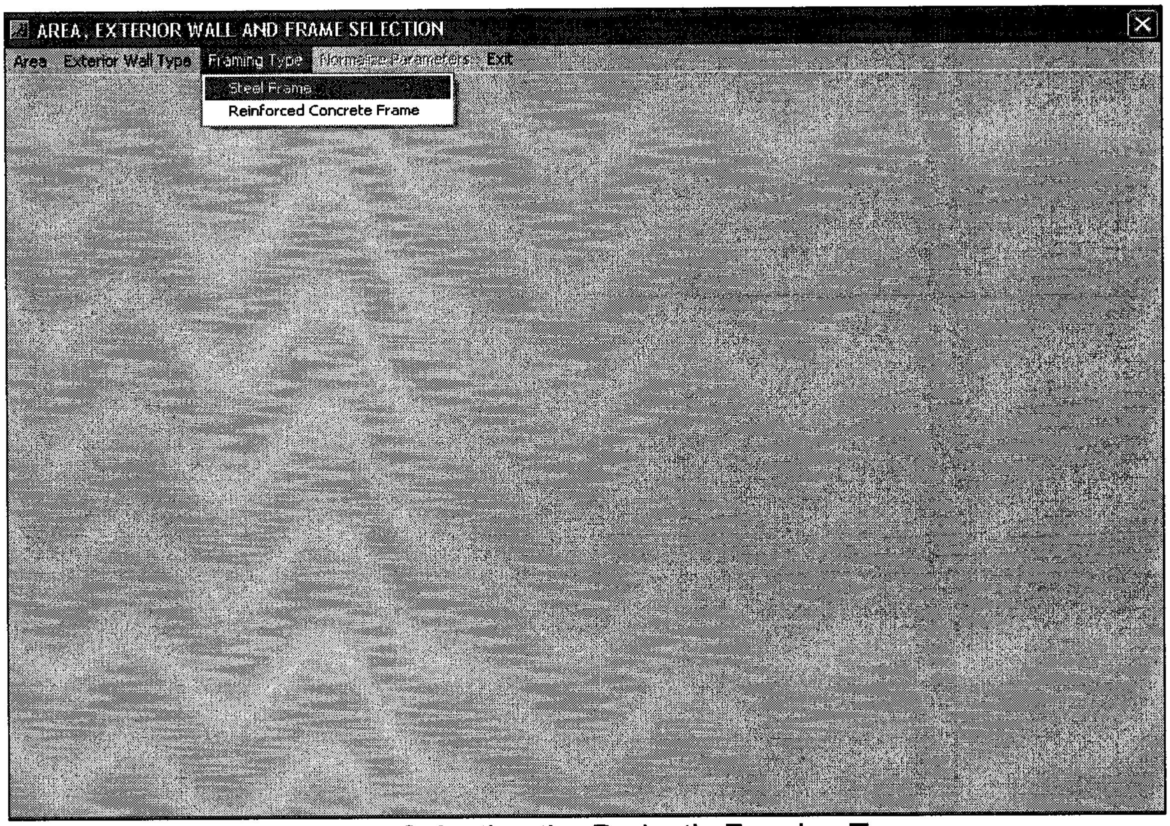


Figure 6.5 Selecting the Project's Framing Type

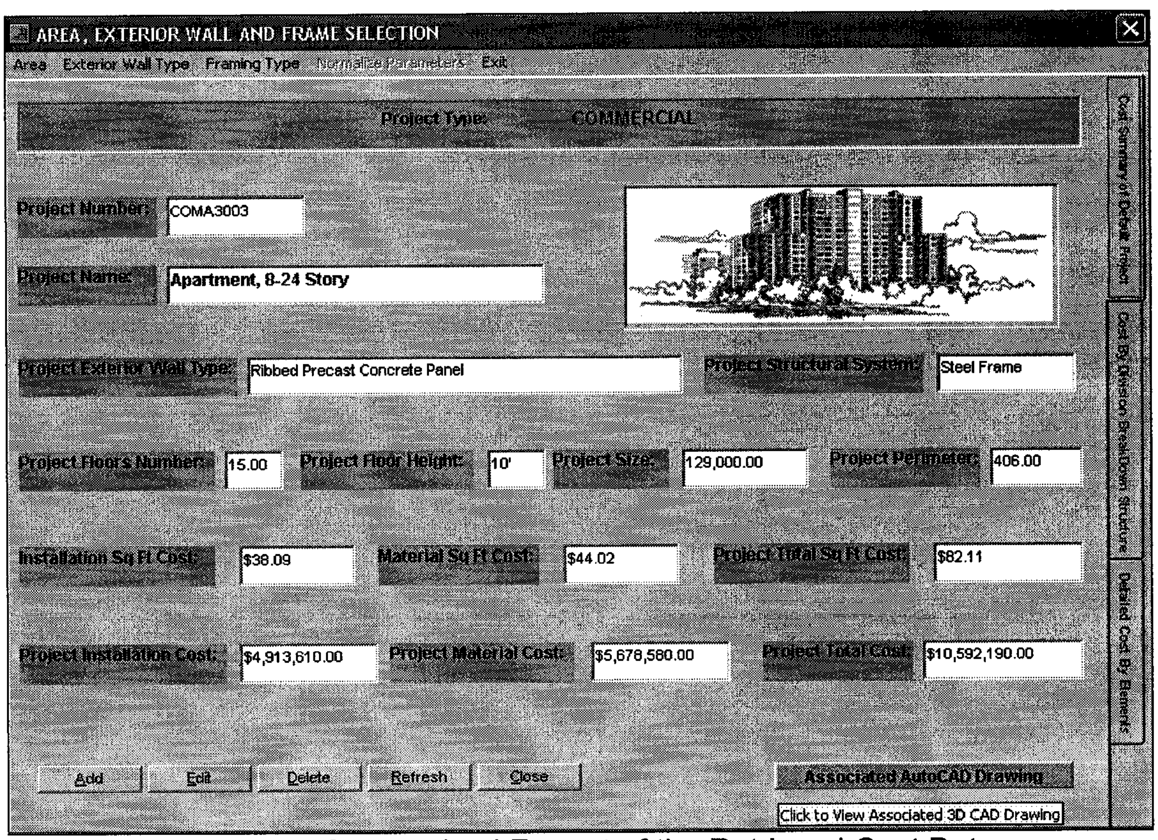
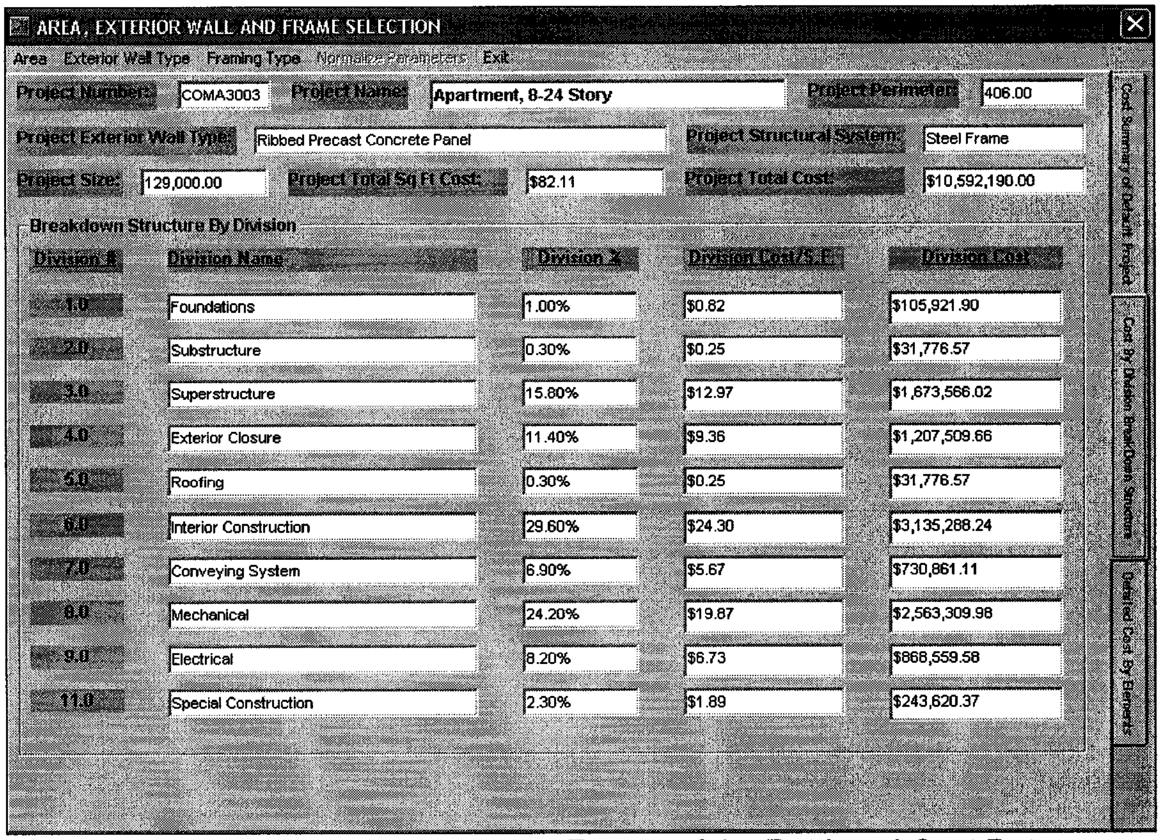
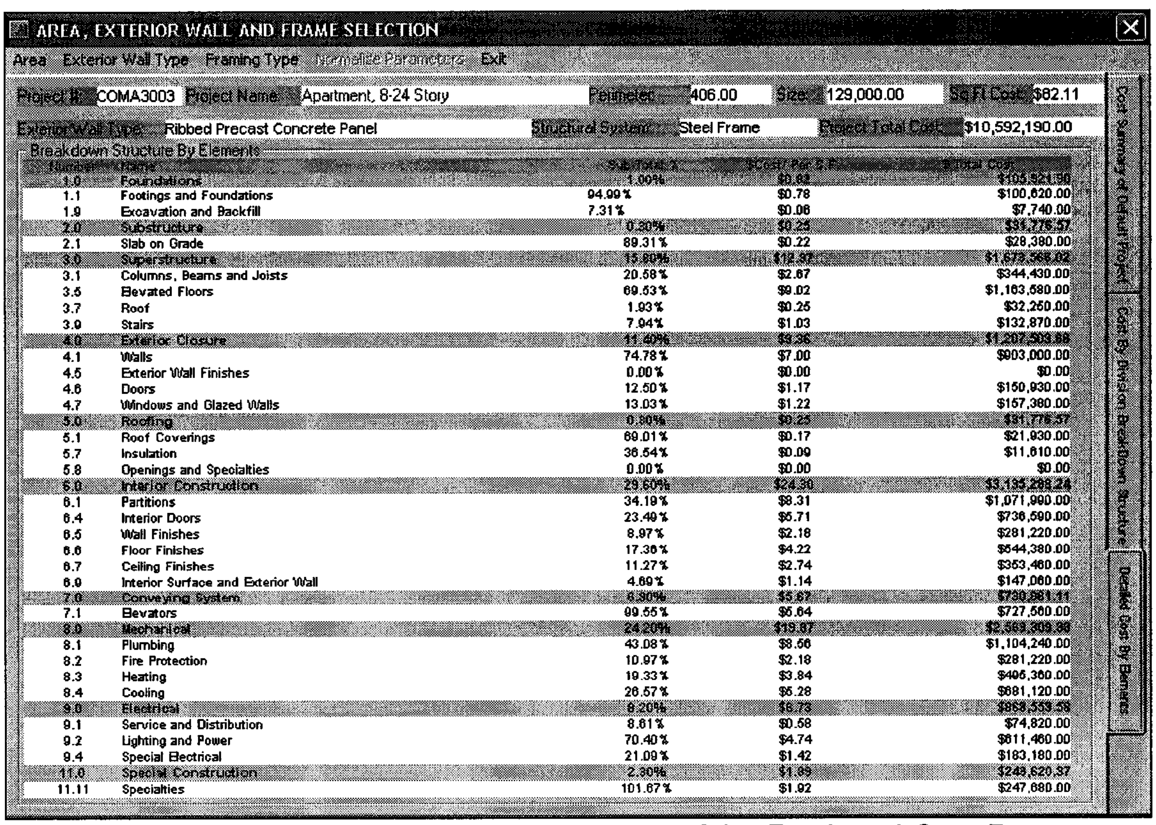


Figure 6.6 Summarized Format of the Retrieved Cost Data



Division #	Division Name	Division %	Division Cost/S.F.	Division Cost
1.0	Foundations	1.00%	$0.82	$105,921.90
2.0	Substructure	0.30%	$0.25	$31,776.57
3.0	Superstructure	15.80%	$12.97	$1,673,566.02
4.0	Exterior Closure	11.40%	$9.36	$1,207,509.66
5.0	Roofing	0.30%	$0.25	$31,776.57
6.0	Interior Construction	29.60%	$24.30	$3,135,288.24
7.0	Conveying System	6.90%	$5.67	$730,861.11
8.0	Mechanical	24.20%	$19.87	$2,563,309.98
9.0	Electrical	8.20%	$6.73	$868,559.58
11.0	Special Construction	2.30%	$1.89	$243,620.37

Figure 6.7 Detailed by Divisions Format of the Retrieved Cost Data



Number	Name	SubTotal %	$Cost/ Per S.F.	Total Cost
1.0	Foundations	1.00%	$0.82	$105,921.90
1.1	Footings and Foundations	94.99%	$0.78	$100,620.00
1.9	Excavation and Backfill	7.31%	$0.06	$7,740.00
2.0	Substructure	0.30%	$0.25	$31,776.57
2.1	Slab on Grade	89.31%	$0.22	$28,380.00
3.0	Superstructure	15.80%	$12.97	$1,673,566.02
3.1	Columns, Beams and Joists	20.58%	$2.67	$344,430.00
3.5	Elevated Floors	69.53%	$9.02	$1,163,580.00
3.7	Roof	1.93%	$0.25	$32,250.00
3.9	Stairs	7.94%	$1.03	$132,870.00
4.0	Exterior Closure	11.40%	$9.36	$1,207,509.66
4.1	Walls	74.78%	$7.00	$903,000.00
4.5	Exterior Wall Finishes	0.00%	$0.00	$0.00
4.6	Doors	12.50%	$1.17	$150,930.00
4.7	Windows and Glazed Walls	13.03%	$1.22	$157,380.00
5.0	Roofing	0.30%	$0.25	$31,776.57
5.1	Roof Coverings	69.01%	$0.17	$21,930.00
5.7	Insulation	36.54%	$0.09	$11,610.00
5.8	Openings and Specialties	0.00%	$0.00	$0.00
6.0	Interior Construction	29.60%	$24.30	$3,135,288.24
6.1	Partitions	34.19%	$8.31	$1,071,990.00
6.4	Interior Doors	23.49%	$5.71	$736,590.00
6.5	Wall Finishes	8.97%	$2.18	$281,220.00
6.6	Floor Finishes	17.36%	$4.22	$544,380.00
6.7	Ceiling Finishes	11.27%	$2.74	$353,460.00
6.9	Interior Surface and Exterior Wall	4.69%	$1.14	$147,060.00
7.0	Conveying System	6.90%	$5.67	$730,861.11
7.1	Elevators	99.55%	$5.64	$727,560.00
8.0	Mechanical	24.20%	$19.87	$2,563,309.98
8.1	Plumbing	43.08%	$8.56	$1,104,240.00
8.2	Fire Protection	10.97%	$2.18	$281,220.00
8.3	Heating	19.33%	$3.84	$496,360.00
8.4	Cooling	26.57%	$5.28	$681,120.00
9.0	Electrical	8.20%	$6.73	$868,559.58
9.1	Service and Distribution	8.61%	$0.58	$74,820.00
9.2	Lighting and Power	70.40%	$4.74	$611,460.00
9.4	Special Electrical	21.09%	$1.42	$183,180.00
11.0	Special Construction	2.30%	$1.89	$243,620.37
11.11	Specialties	101.67%	$1.92	$247,680.00

Figure 6.8 Detailed by Elements Format of the Retrieved Cost Data

Clicking the "Associated AutoCAD Drawing" button shown in Figure 6.6 accesses the associated 3D-CAD drawing. Instantly the system opens the mentioned drawing as shown in Figure 6.9.

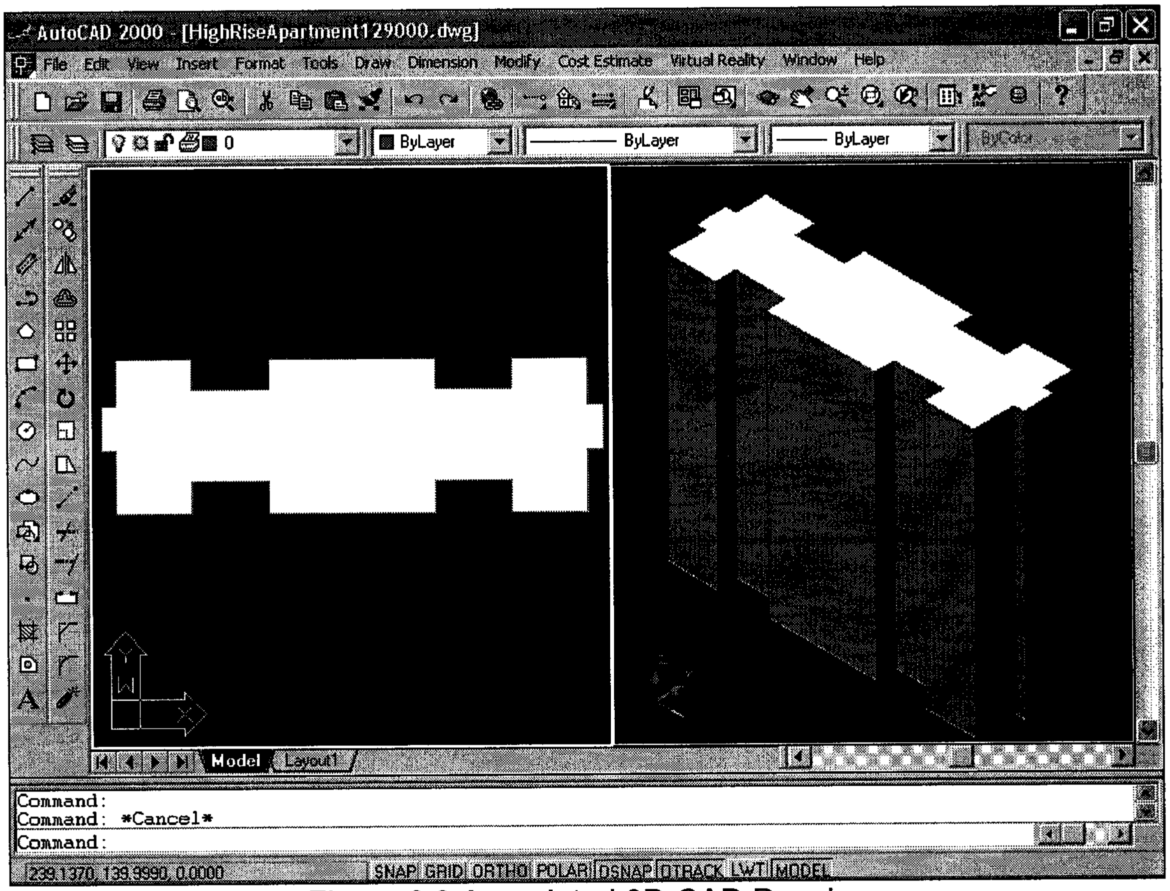


Figure 6.9 Associated 3D-CAD Drawing

Obviously from the AutoCAD customized drop down menus, the user can acquire the drawing's parameters as shown in Figures 6.10 and 6.11. That drawing has a total floor area of 129,000 ft^2, a floor area of 8,600 ft^2, 15 stories, and a perimeter of 547 ft; therefore, it has to be adjusted in a way that meets the actual values of the project at hand. Hence, we have modified the floor area from 8,600 to 4,621 ft^2, the perimeter from 547 to 401 ft, and the number of floors from 15 to 28, and the total floor area to 129,033 ft^2. This is shown in Figures 6.12 to 6.13.

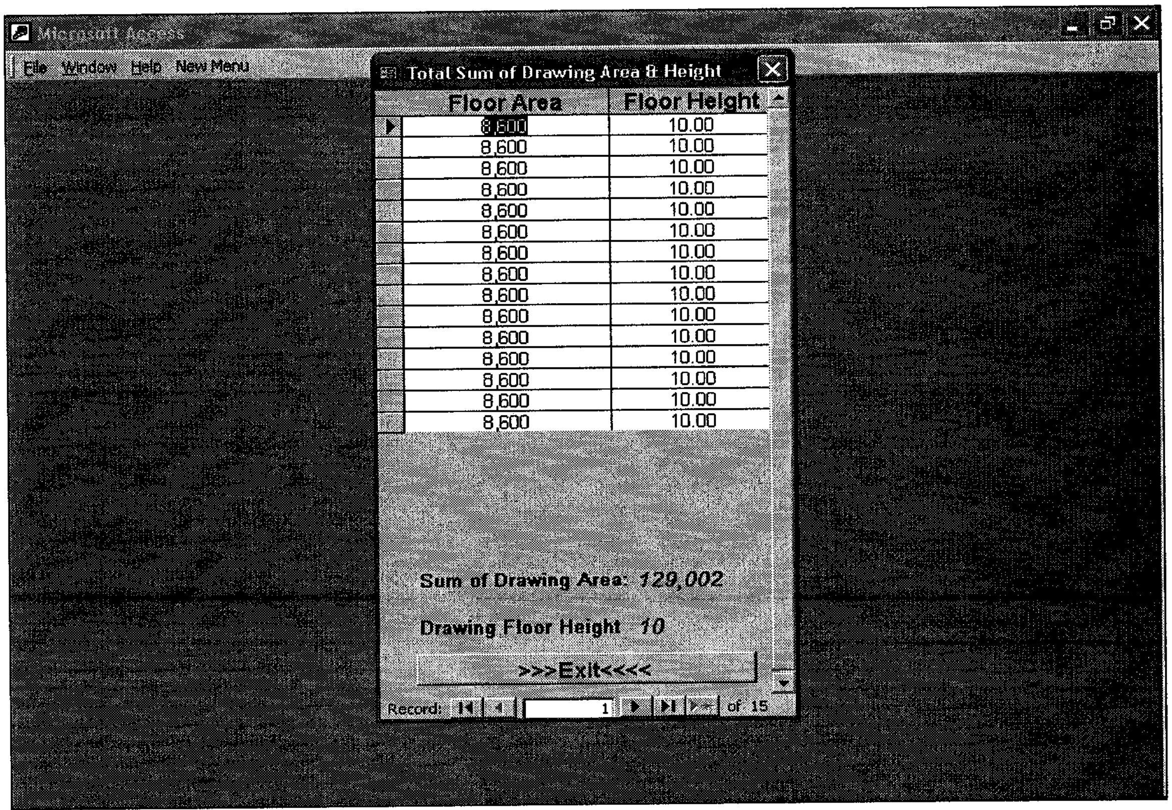


Figure 6.10 Associated Drawing's Parameters

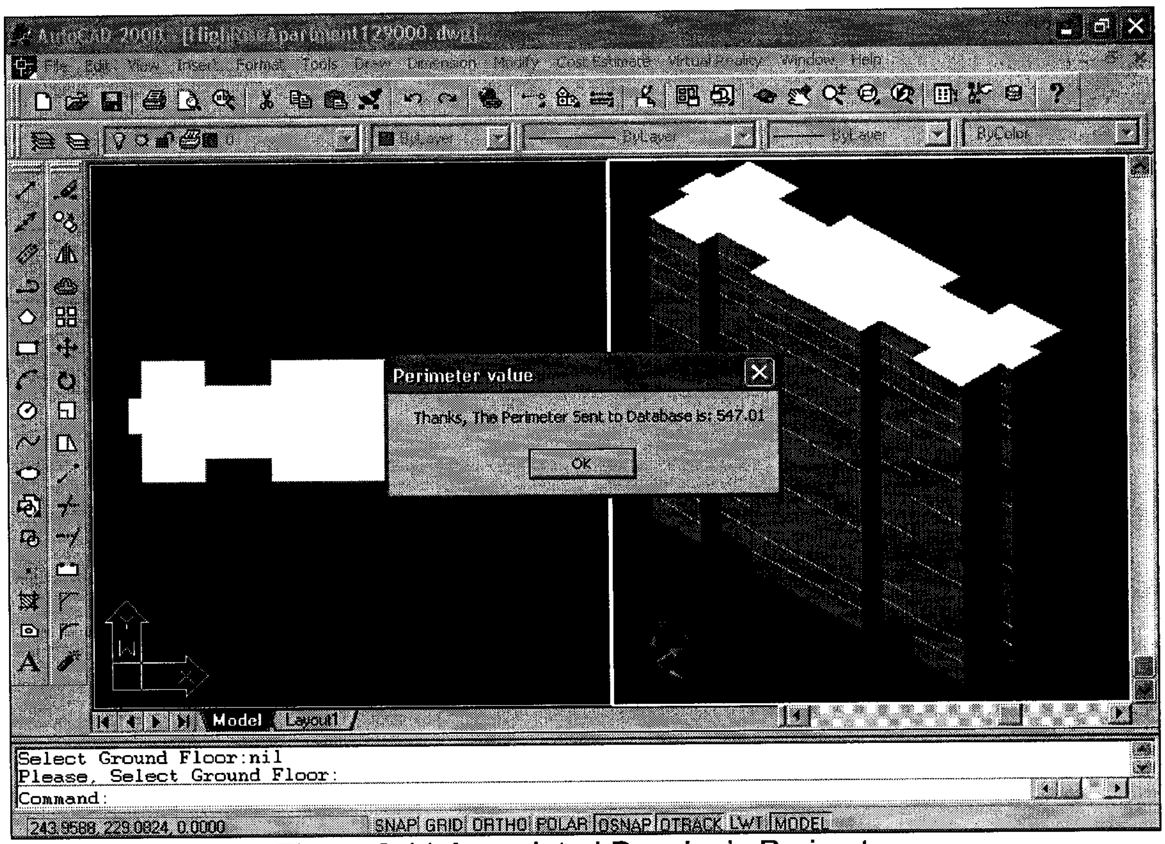


Figure 6.11 Associated Drawing's Perimeter

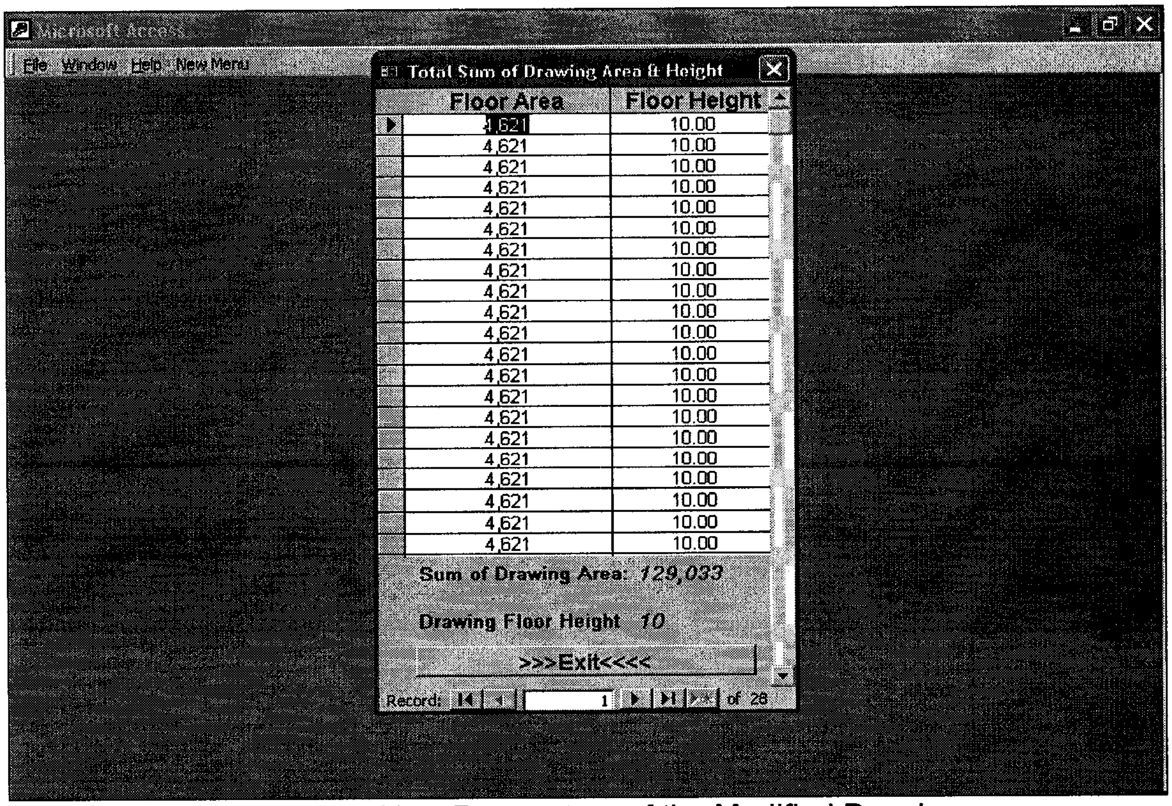


Figure 6.12 New Parameters of the Modified Drawing

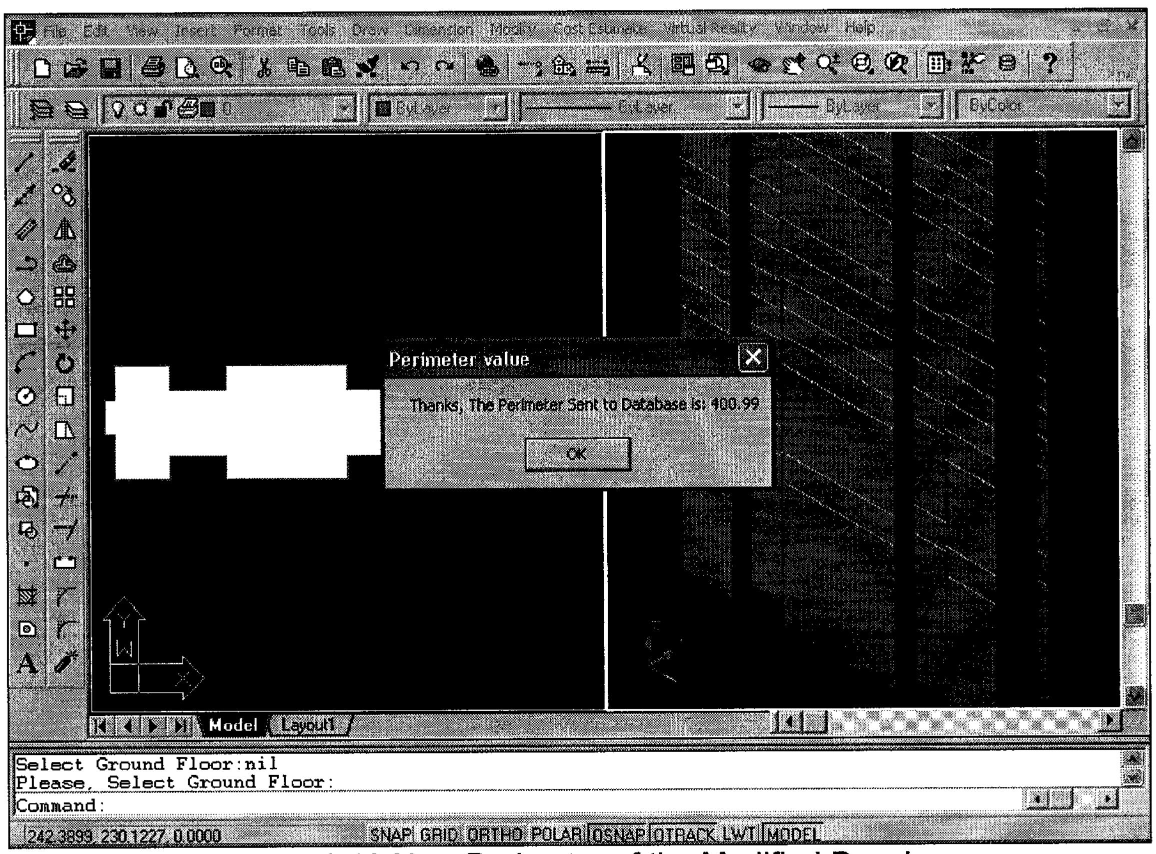


Figure 6.13 New Perimeter of the Modified Drawing

Based on the retrieved parameters from the modified drawing a new cost estimate is generated after executing all needed adjustments. These adjustments are based on size, perimeter, inflation, and location as exemplified in Figure 6.14.

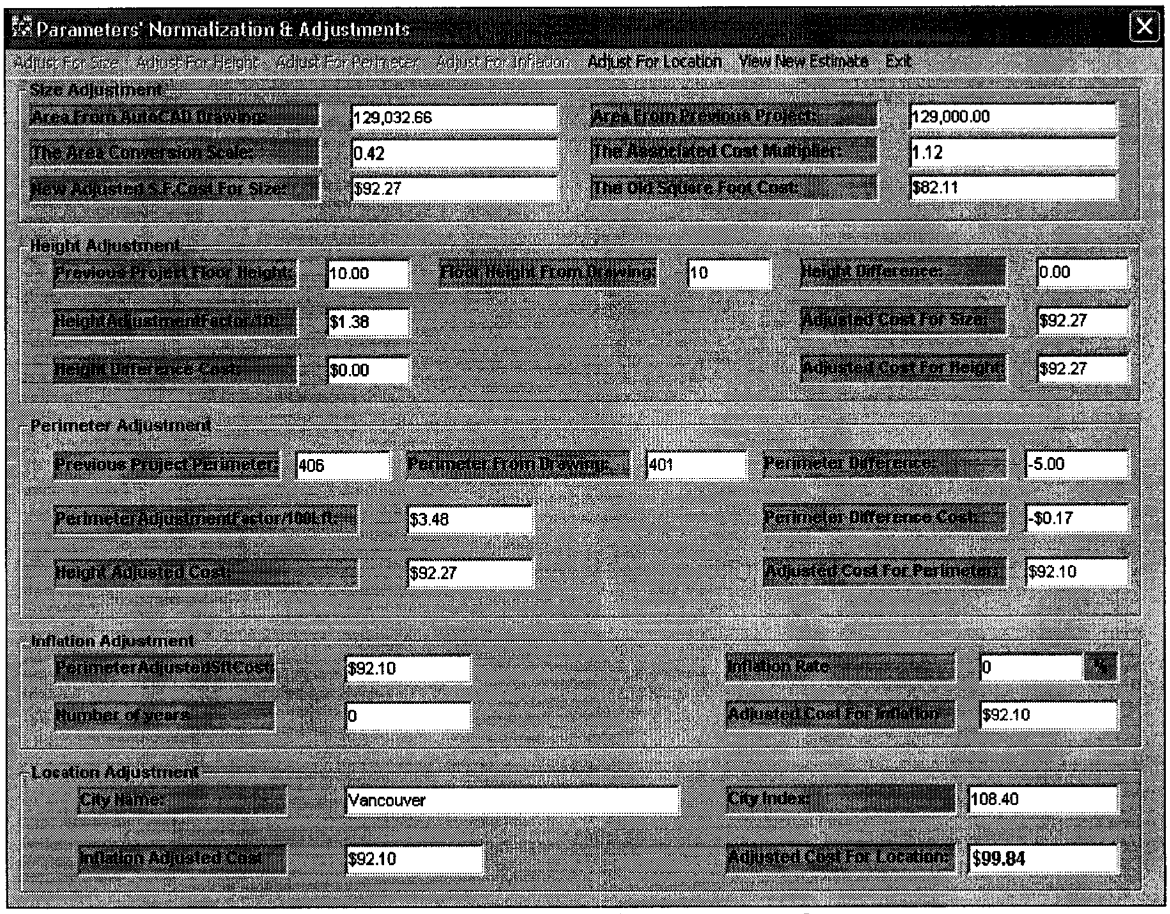


Figure 6.14 Adjusted Square Foot Cost

It is to be noted that the floor height of 10 ft has not been changed and thus no adjustment for height is required. Furthermore, since the direct construction cost of the actual project has already been adjusted from year 1996 to 2000, there is no need to adjust for inflation. Therefore, a value of zero is entered in the "Inflation Rate" and the "Number of years" as shown in Figure 6.14. Nevertheless, an adjustment for location is required and is accordingly based on this square feet adjusted cost for location. A new cost estimate is generated as displayed in Figures 6.15 to 6.18

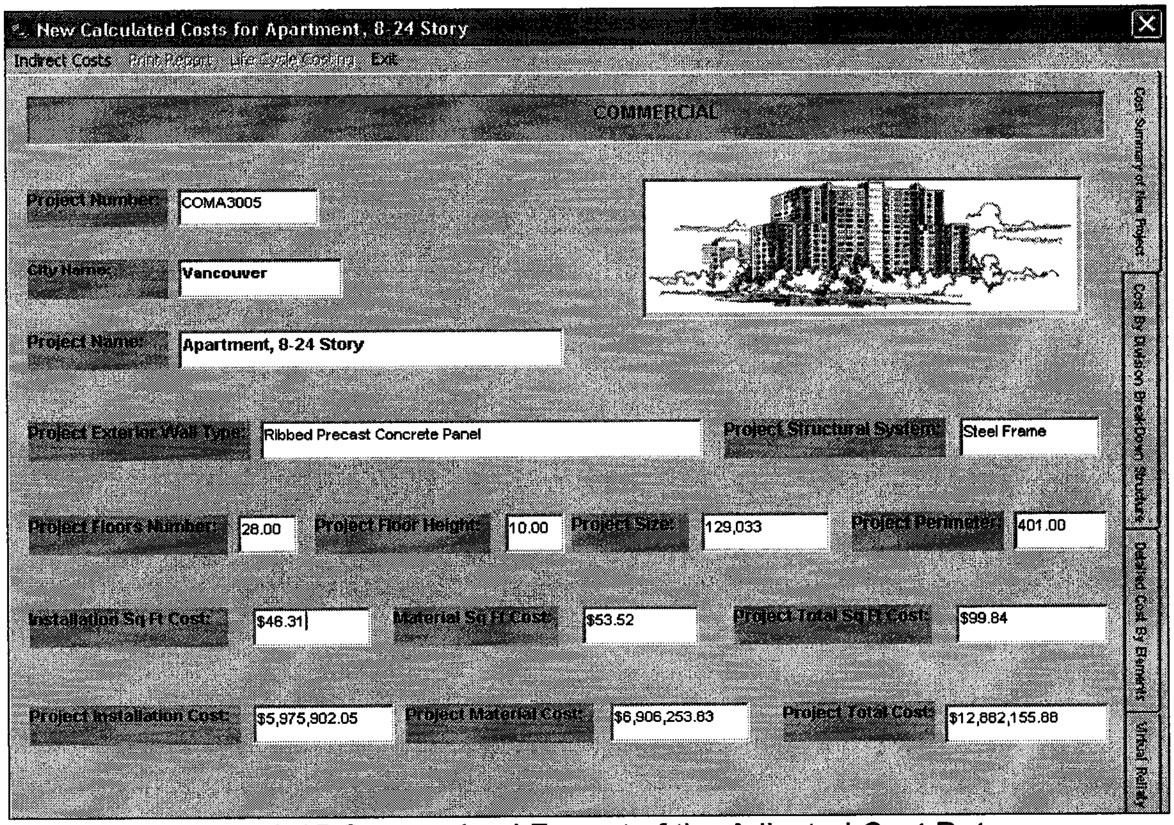


Figure 6.15 Summarized Format of the Adjusted Cost Data

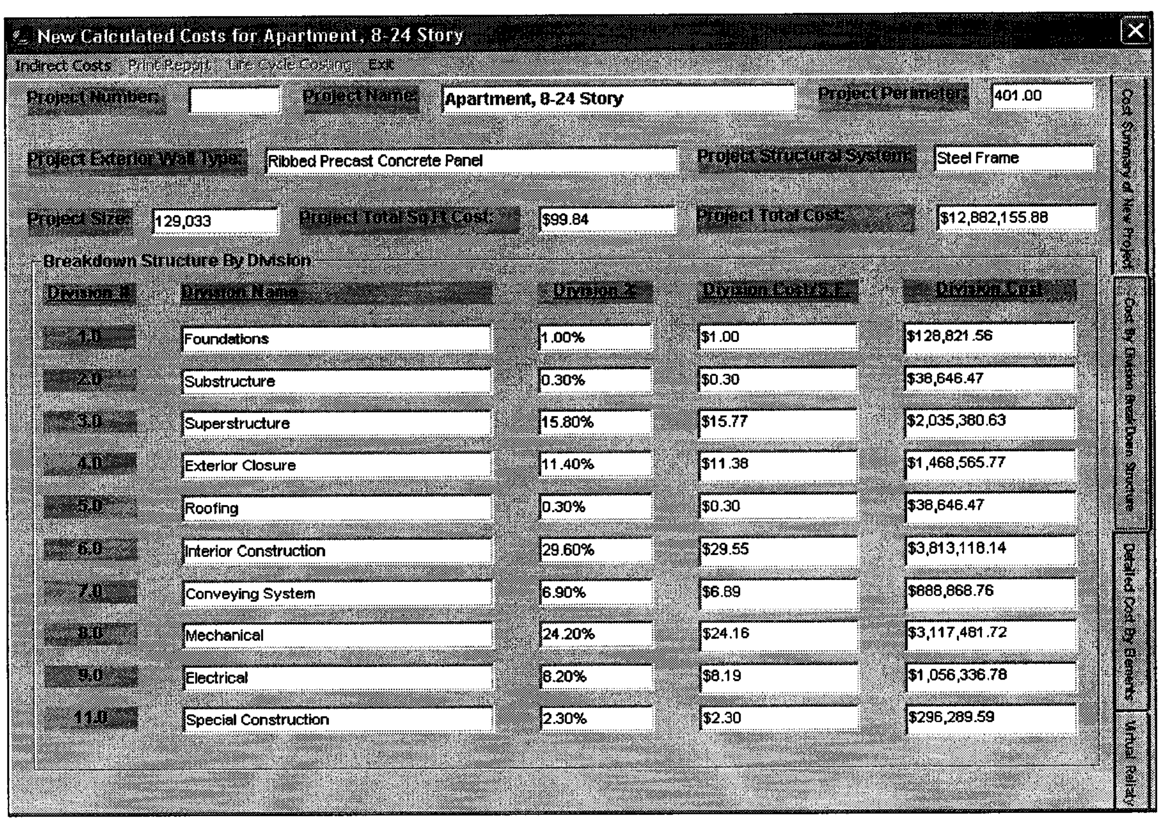
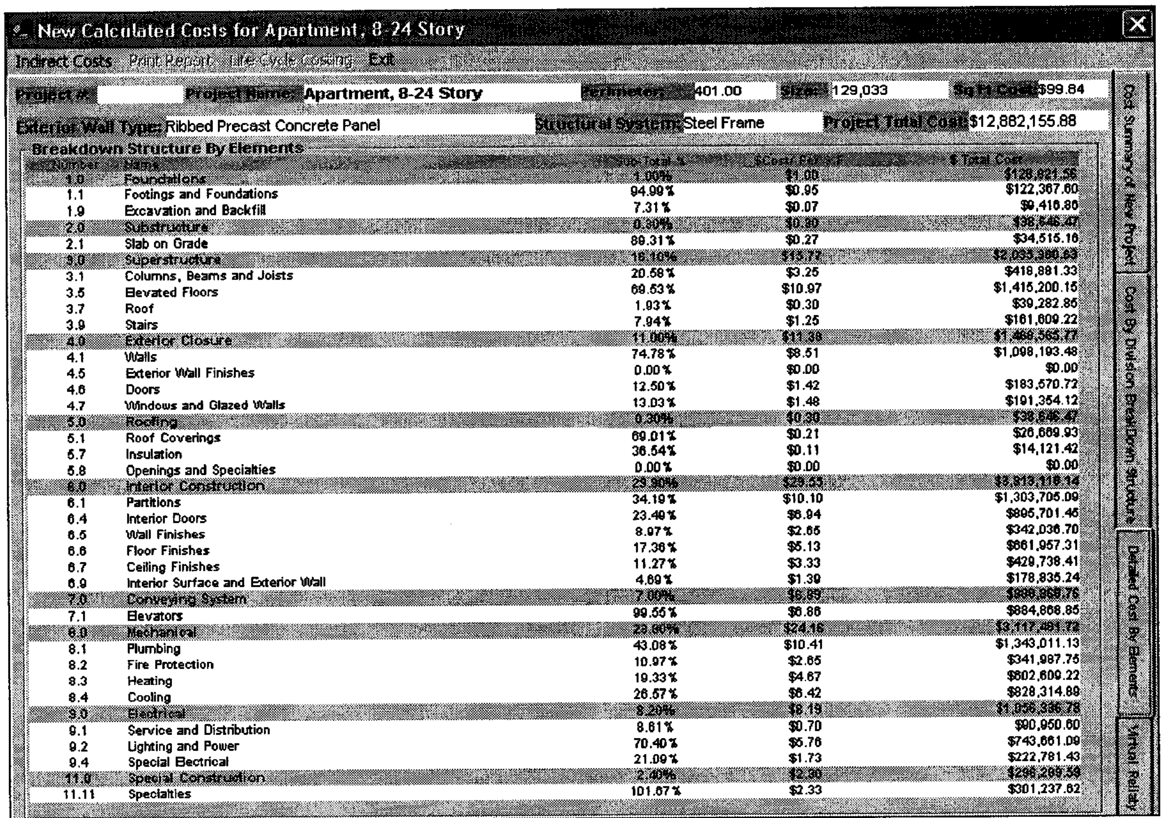


Figure 6.16 Detailed by Divisions Format of Adjusted Cost Data



New Calculated Costs for Apartment, 8-24 Story

Indirect Costs Print Report Life Cycle Costing Exit

Project #: | Project Name: Apartment, 8-24 Story | Perimeter: 401.00 | Size: 129,033 | Sq Ft Cost: $99.84

Exterior Wall Type: Ribbed Precast Concrete Panel | Structural System: Steel Frame | Project Total Cost: $12,882,155.88

Breakdown Structure By Elements

Number	Name	Sub-Total %	$Cost/ Per SF	$ Total Cost
1.0	Foundations	1.00%	$1.00	$128,921.56
1.1	Footings and Foundations	94.99%	$0.95	$122,367.60
1.9	Excavation and Backfill	7.31%	$0.07	$9,416.86
2.0	Substructure	0.30%	$0.30	$38,646.47
2.1	Slab on Grade	89.31%	$0.27	$34,515.16
3.0	Superstructure	16.10%	$15.77	$2,035,380.63
3.1	Columns, Beams and Joists	20.58%	$3.25	$418,881.33
3.5	Elevated Floors	69.53%	$10.97	$1,415,200.15
3.7	Roof	1.93%	$0.30	$39,282.86
3.9	Stairs	7.94%	$1.25	$161,609.22
4.0	Exterior Closure	11.00%	$11.38	$1,468,565.77
4.1	Walls	74.78%	$8.51	$1,098,193.48
4.5	Exterior Wall Finishes	0.00%	$0.00	$0.00
4.6	Doors	12.50%	$1.42	$183,570.72
4.7	Windows and Glazed Walls	13.03%	$1.48	$191,354.12
5.0	Roofing	0.30%	$0.30	$38,646.47
5.1	Roof Coverings	69.01%	$0.21	$26,669.93
5.7	Insulation	36.54%	$0.11	$14,121.42
5.8	Openings and Specialties	0.00%	$0.00	$0.00
6.0	Interior Construction	29.90%	$29.55	$3,813,118.14
6.1	Partitions	34.19%	$10.10	$1,303,705.09
6.4	Interior Doors	23.49%	$6.94	$895,701.46
6.5	Wall Finishes	8.97%	$2.65	$342,036.70
6.6	Floor Finishes	17.36%	$5.13	$661,957.31
6.7	Ceiling Finishes	11.27%	$3.33	$429,738.41
6.9	Interior Surface and Exterior Wall	4.69%	$1.39	$178,835.24
7.0	Conveying System	7.00%	$6.89	$888,968.76
7.1	Elevators	99.55%	$6.86	$884,868.85
8.0	Mechanical	23.60%	$24.16	$3,117,481.72
8.1	Plumbing	43.08%	$10.41	$1,343,011.13
8.2	Fire Protection	10.97%	$2.65	$341,987.75
8.3	Heating	19.33%	$4.67	$602,609.22
8.4	Cooling	26.57%	$6.42	$828,314.88
9.0	Electrical	8.20%	$8.19	$1,056,336.78
9.1	Service and Distribution	8.61%	$0.70	$90,950.60
9.2	Lighting and Power	70.40%	$5.76	$743,661.09
9.4	Special Electrical	21.09%	$1.73	$222,781.43
11.0	Special Construction	2.40%	$2.30	$296,289.59
11.11	Specialties	101.67%	$2.33	$301,237.62

Cost Summary of New Project | Cost By Division BreakDown Structure | Detailed Cost By Elements | Virtual Reality

Figure 6.17 Detailed by Elements Format of the Adjusted Cost Data

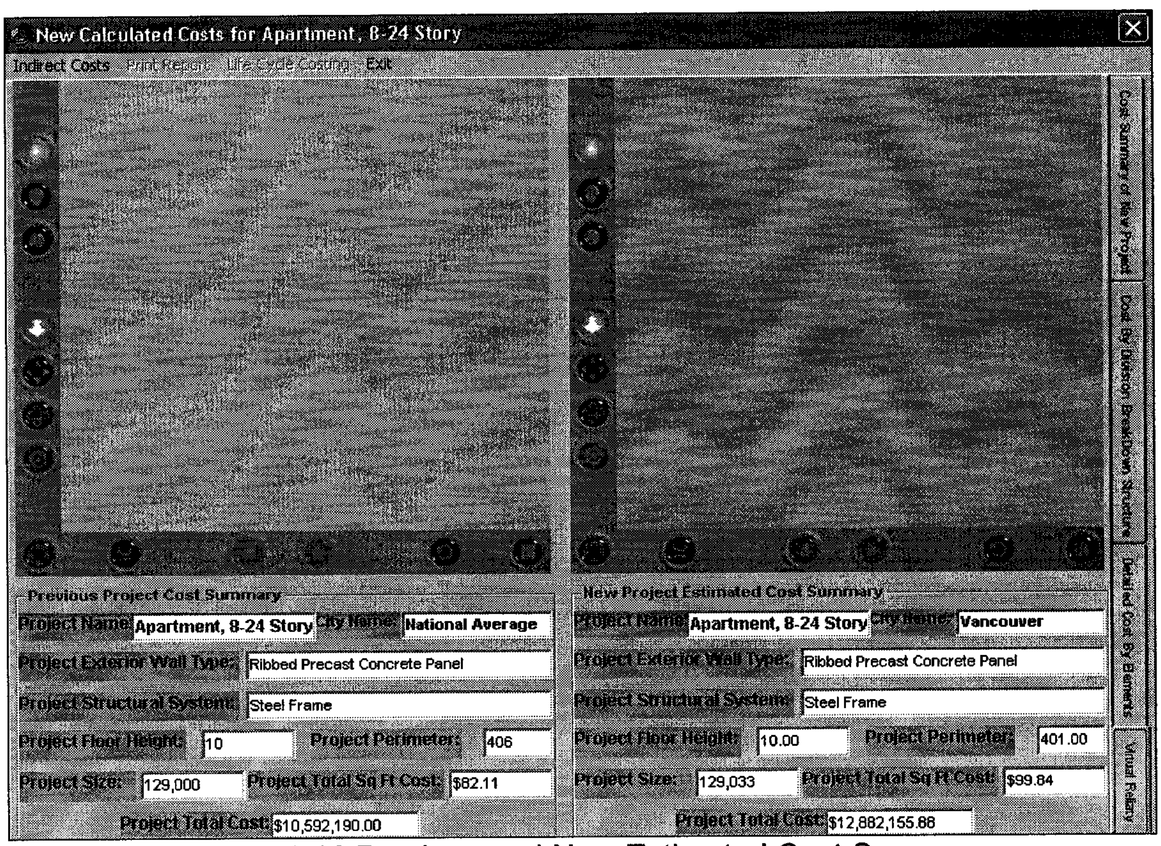


Figure 6.18 Previous and New Estimated Cost Summary

Adjusting the $10,592,190 shown in Figure 6.18 from National Average cost to Vancouver gives us a value of $11,481,934; this is for an area of 129,000 and a perimeter of 406. Comparing this value with the New Project Estimated Cost given in Figure 6.18, that is, $12,882,156 for an area of 129,033 and perimeter of 401, would show a difference of $1,400,222, which is around 12.2%. Based on AACE International Classification shown in Table 2.1 the expected range of accuracy for class 5 estimates where the level of project definition is between 0% and 2% is from –50% to 100%. While for a Class 4 estimate that has a project level of definition ranging between 1% and 5% the expected accuracy level is –30% to +50%. Therefore, the system's validation is above the acceptable level, which means its outcomes are dependable and hold a high level of accuracy. After entering the indirect costs as given in Figure 6.19, we are provided by the system with a list of four different types of output reports that consist of two graphical and two tabulated and are asked to select the desired one(s). Figures 6.20 to 6.26 show these different types of reports. Nevertheless, as mentioned previously in this chapter, the total project costs of $23,029,641 include a land fee of $5,042,964. If we remove this value, the actual project cost for year 1996 would be $17,986,677 and for year 2000 would be $20,244,163. The value calculated by the system after entering the indirect costs is $18,073,665. Comparing the two values shows a difference of -$2,170,498, which corresponds to –12.00%. This is an acceptable result and accordingly demonstrates the capability of the system in supplying a high level of accuracy for proposed projects at their feasible stage.

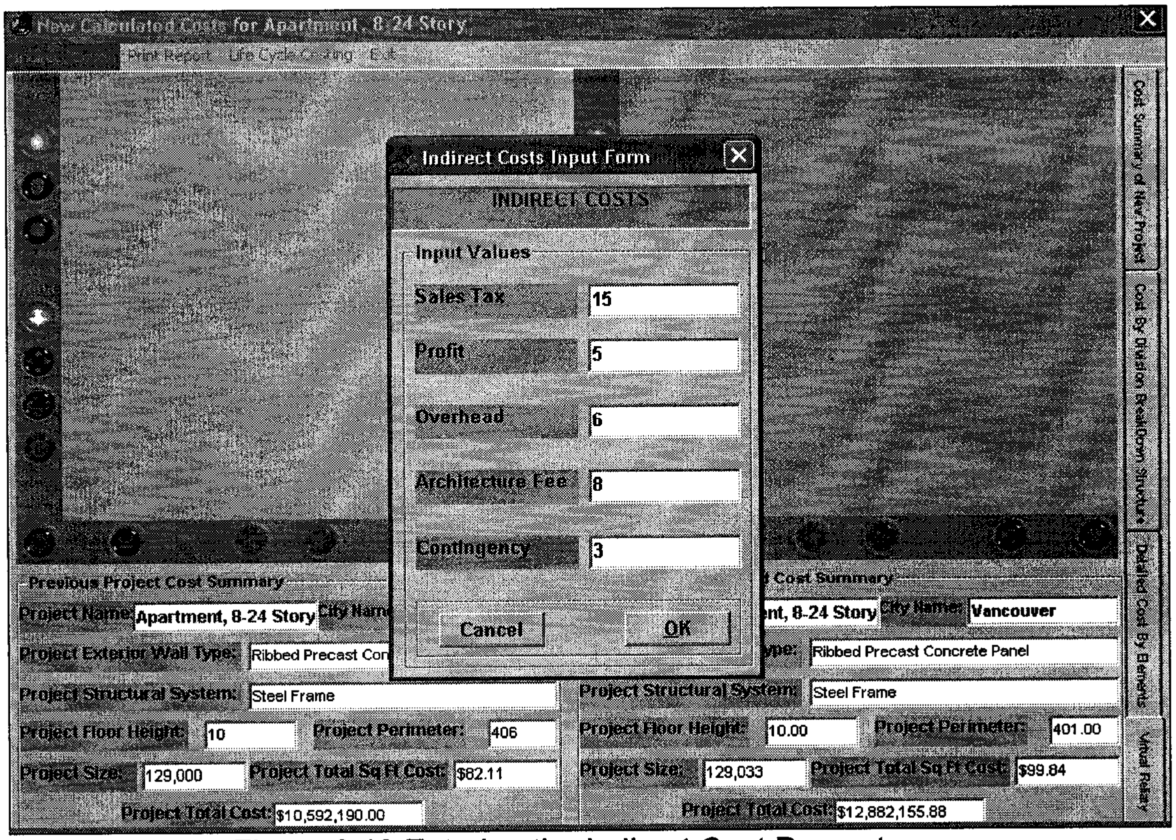


Figure 6.19 Entering the Indirect Cost Percentage

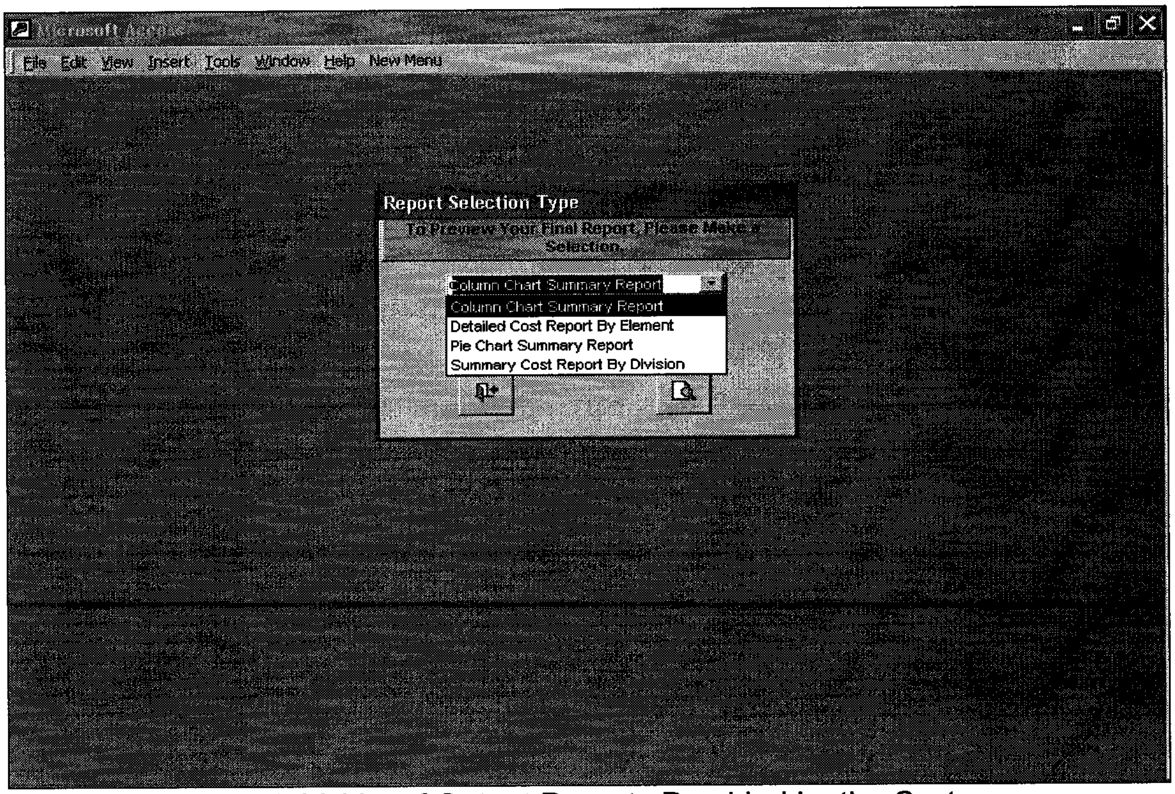


Figure 6.20 List of Output Reports Provided by the System

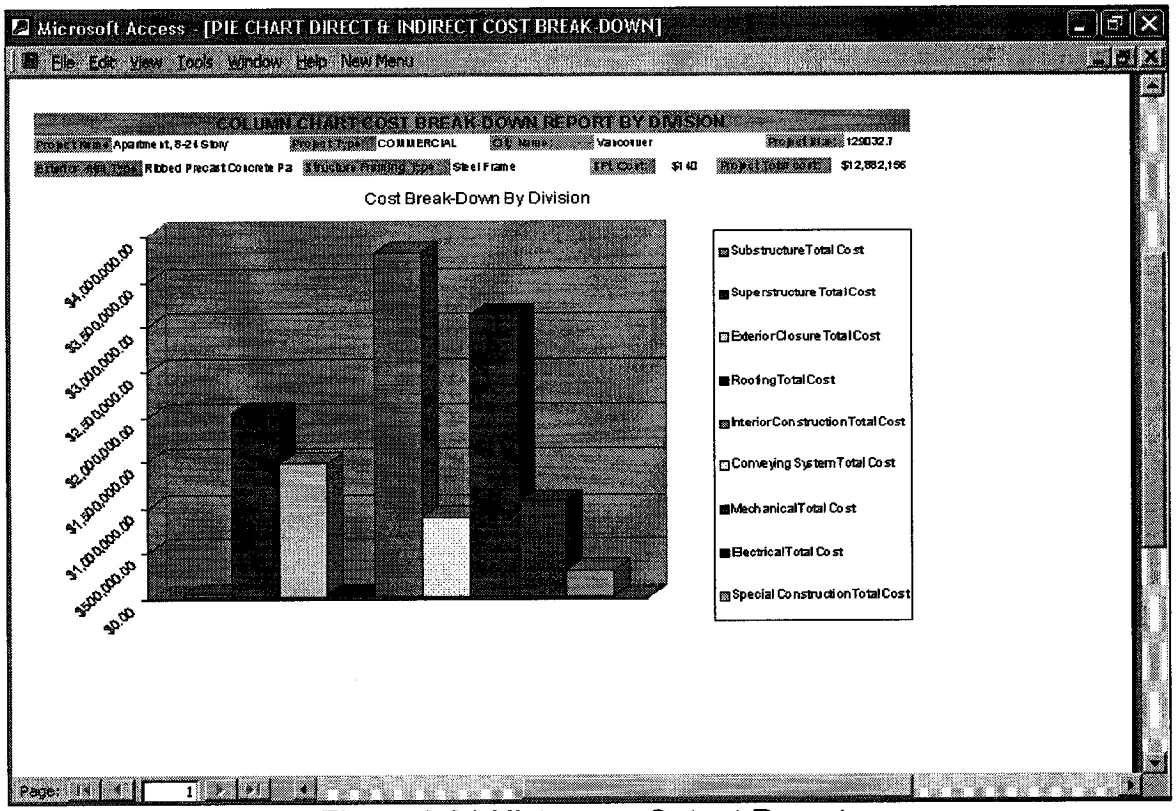
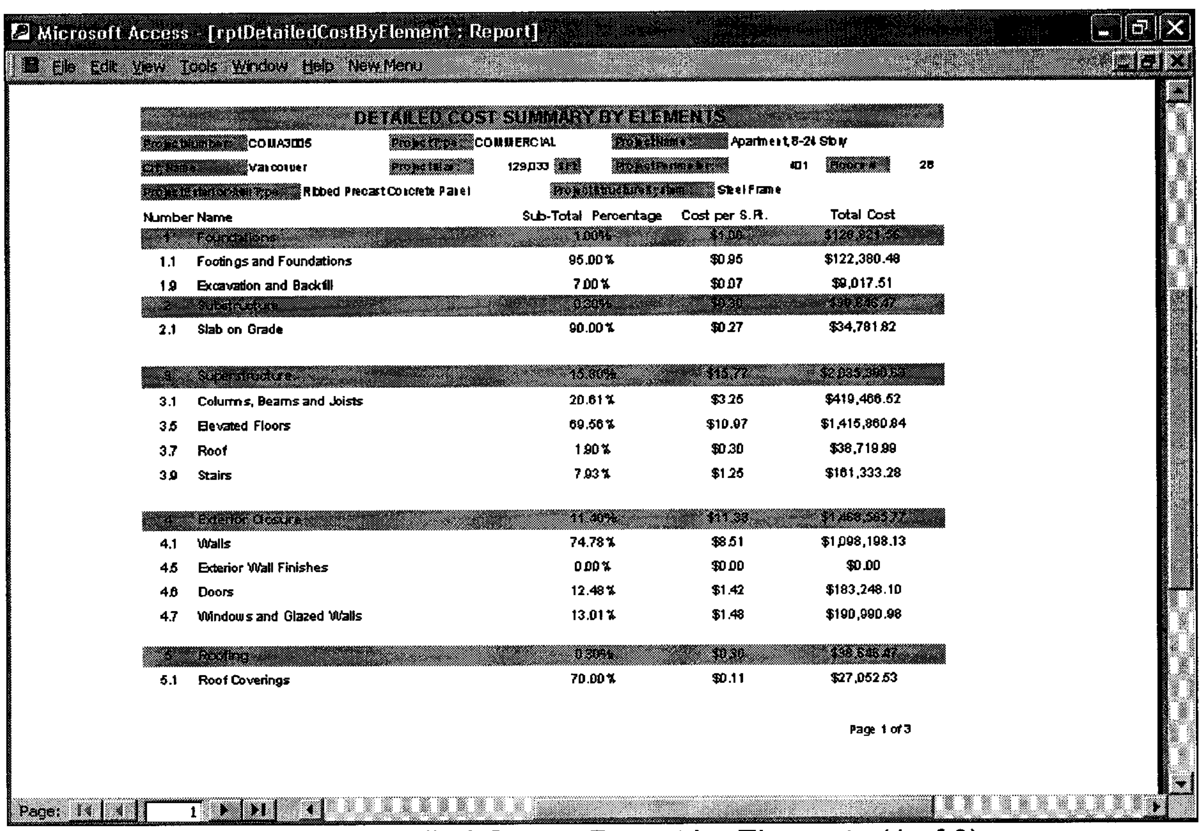


Figure 6.21 Histogram Output Report



Microsoft Access - [rptDetailedCostByElement : Report]

DETAILED COST SUMMARY BY ELEMENTS

COMA3005 COMMERCIAL Apartment, 8-24 Story

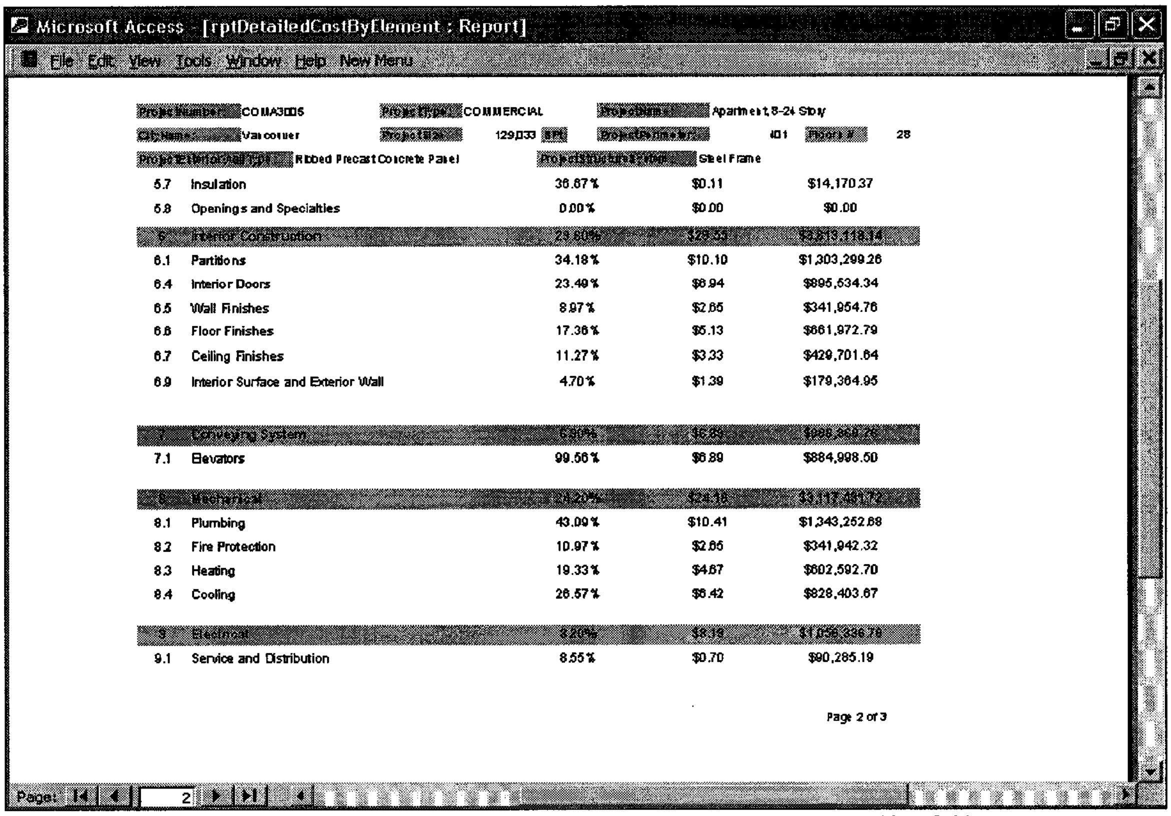
Vancouver 129,033 401 28

Ribbed Precast Concrete Panel Steel Frame

Number	Name	Sub-Total Percentage	Cost per S.Ft.	Total Cost
1	Foundations	1.00%	$1.00	[illegible]
1.1	Footings and Foundations	95.00%	$0.95	$122,380.48
1.9	Excavation and Backfill	7.00%	$0.07	$9,017.51
2	Substructure	0.30%	$0.30	[illegible]
2.1	Slab on Grade	90.00%	$0.27	$34,781.82
3	Superstructure	15.80%	$15.77	[illegible]
3.1	Columns, Beams and Joists	20.61%	$3.25	$419,466.52
3.5	Elevated Floors	69.56%	$10.97	$1,415,860.84
3.7	Roof	1.90%	$0.30	$38,719.99
3.9	Stairs	7.93%	$1.25	$161,333.28
4	Exterior Closure	11.40%	$11.38	[illegible]
4.1	Walls	74.78%	$8.51	$1,098,198.13
4.5	Exterior Wall Finishes	0.00%	$0.00	$0.00
4.6	Doors	12.48%	$1.42	$183,248.10
4.7	Windows and Glazed Walls	13.01%	$1.48	$190,990.98
5	Roofing	0.30%	$0.30	[illegible]
5.1	Roof Coverings	70.00%	$0.11	$27,052.53

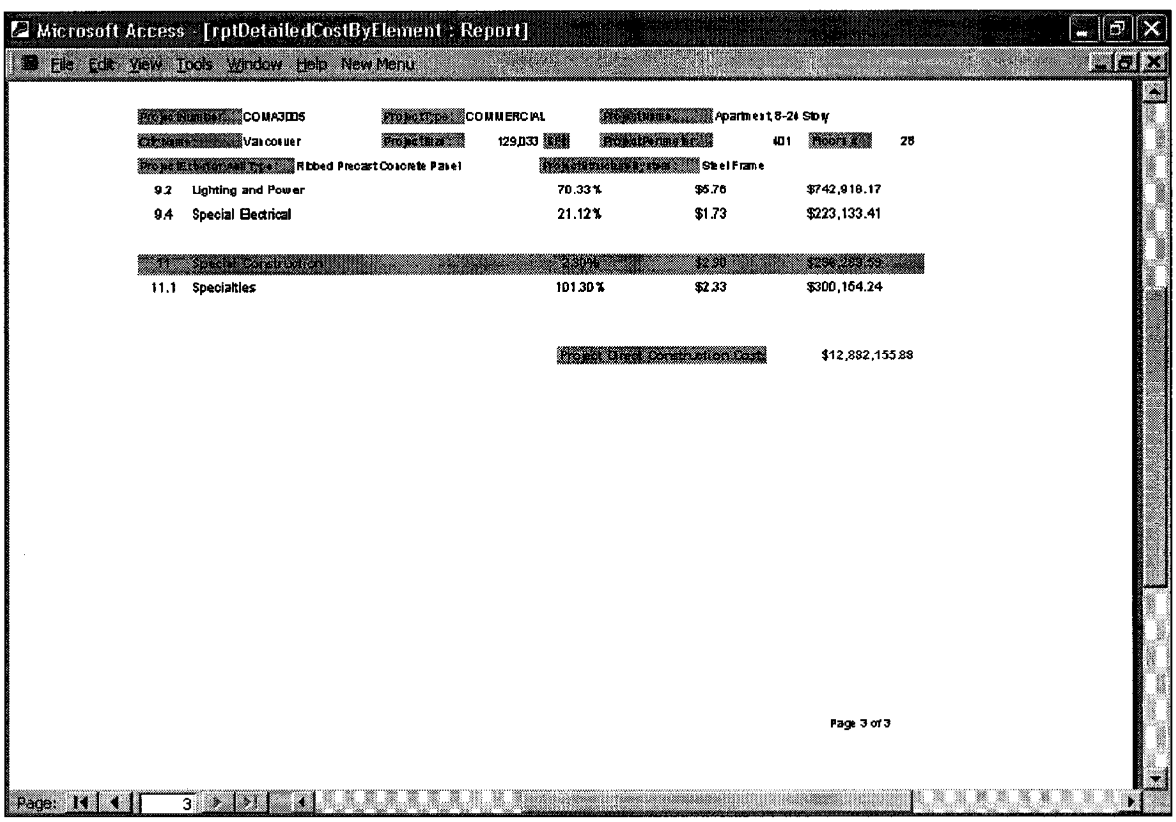
Page 1 of 3

Figure 6.22 Detailed Output Report by Elements (1 of 3)



5.7	Insulation	36.67%	$0.11	$14,170.37
5.8	Openings and Specialties	0.00%	$0.00	$0.00
6	Interior Construction	29.60%	$28.53	$3,813,118.14
6.1	Partitions	34.18%	$10.10	$1,303,299.26
6.4	Interior Doors	23.49%	$6.94	$895,634.34
6.5	Wall Finishes	8.97%	$2.65	$341,954.76
6.6	Floor Finishes	17.36%	$5.13	$661,972.79
6.7	Ceiling Finishes	11.27%	$3.33	$429,701.64
6.9	Interior Surface and Exterior Wall	4.70%	$1.39	$179,364.95
7	Conveying System	6.90%	$6.89	$888,868.26
7.1	Elevators	99.56%	$6.89	$884,998.50
8	Mechanical	24.20%	$24.16	$3,117,481.72
8.1	Plumbing	43.09%	$10.41	$1,343,252.68
8.2	Fire Protection	10.97%	$2.65	$341,942.32
8.3	Heating	19.33%	$4.67	$602,592.70
8.4	Cooling	26.57%	$6.42	$828,403.67
9	Electrical	8.20%	$8.19	$1,056,336.78
9.1	Service and Distribution	8.55%	$0.70	$90,285.19

Figure 6.23 Detailed Output Report by Elements (2 of 3)



9.2	Lighting and Power	70.33%	$5.76	$742,918.17
9.4	Special Electrical	21.12%	$1.73	$223,133.41
11	Special Construction	2.30%	$2.30	$296,283.59
11.1	Specialties	101.30%	$2.33	$300,164.24
		Project Direct Construction Cost:		$12,882,155.88

Figure 6.24 Detailed Output Report by Elements (3 of 3)

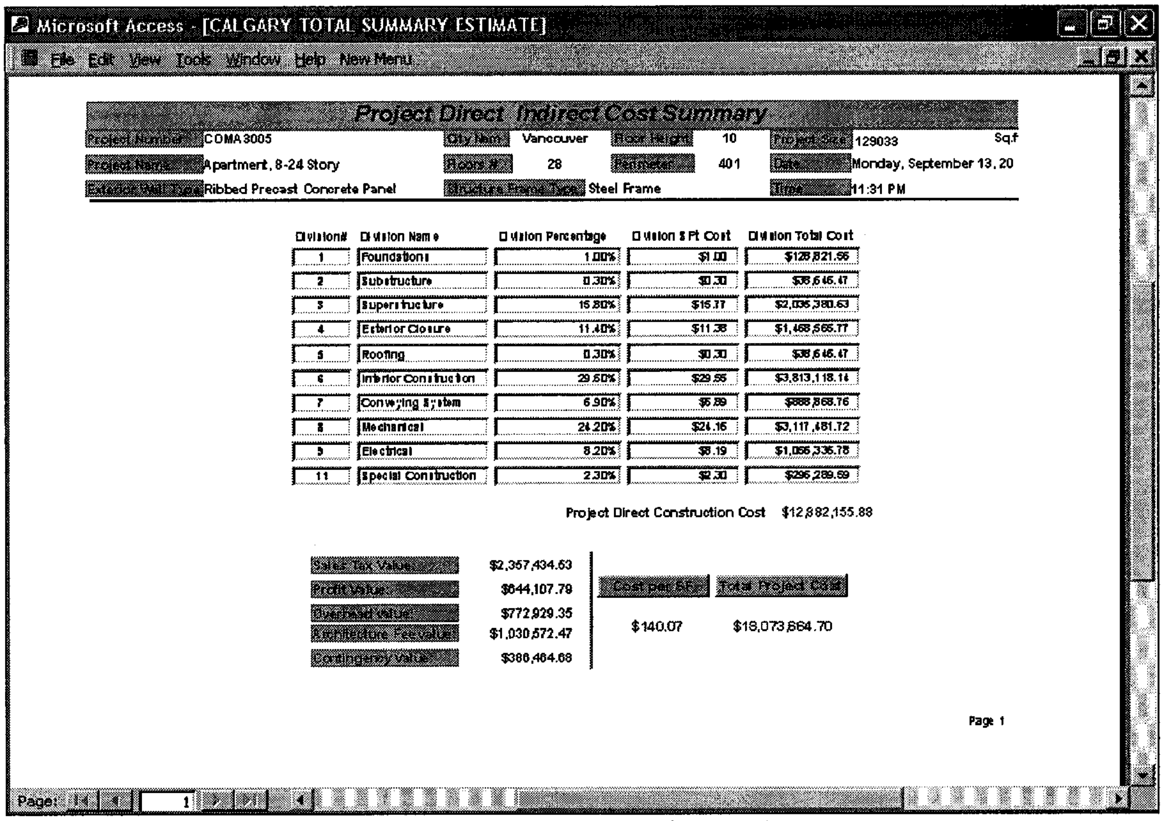


Figure 6.25 Summarized Output Report

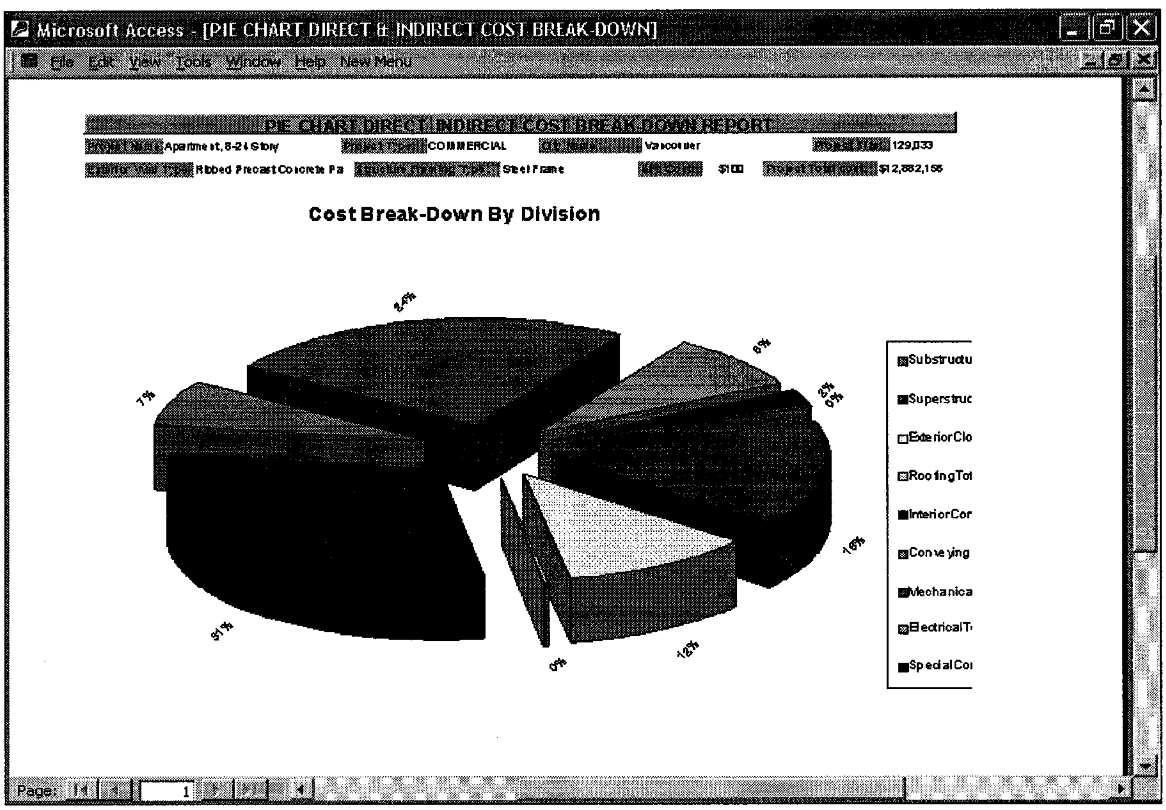


Figure 6.26 Pie-Chart Output Report

Nonetheless, we were not able to gather actual data about the cost of running the actual building. For that reason we are going to use the system to forecast these costs without any level of comparison. By selecting the "Life Cycle Costing" top menu and the "Forecast Project LCC" button as shown in Figure 6.27, the system immediately opens the form shown in Figure 6.28, asking us to enter some necessary data so that the module forecasts the LCC.

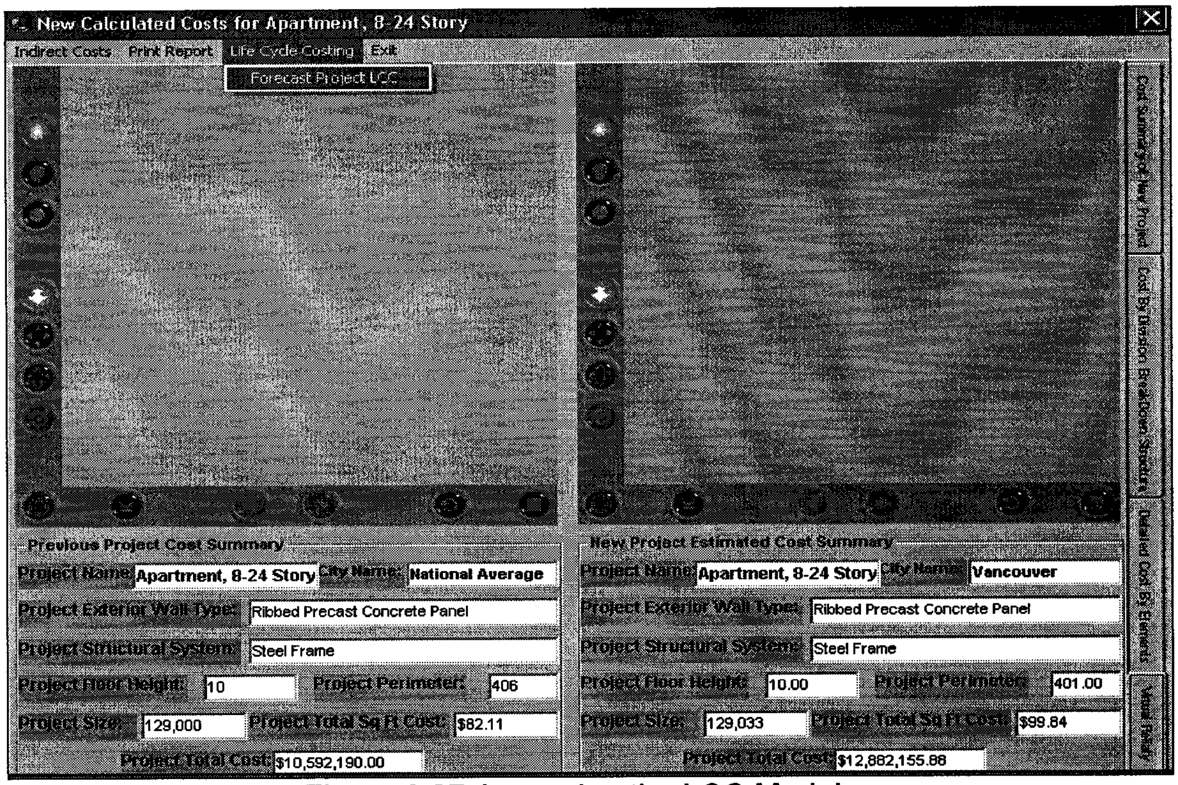


Figure 6.27 Accessing the LCC Module

The data needed consists of the land area, land price/ft^2, office rental area, retail space area, other income, salvage value, LCC period of study, office rental rate/ft^2, interest rate and inflation rate as exemplified in Figure 6.28. Once all these data are entered, the system supplies us with a list of output reports to select from, as shown in Figures 6.29 to 6.35.

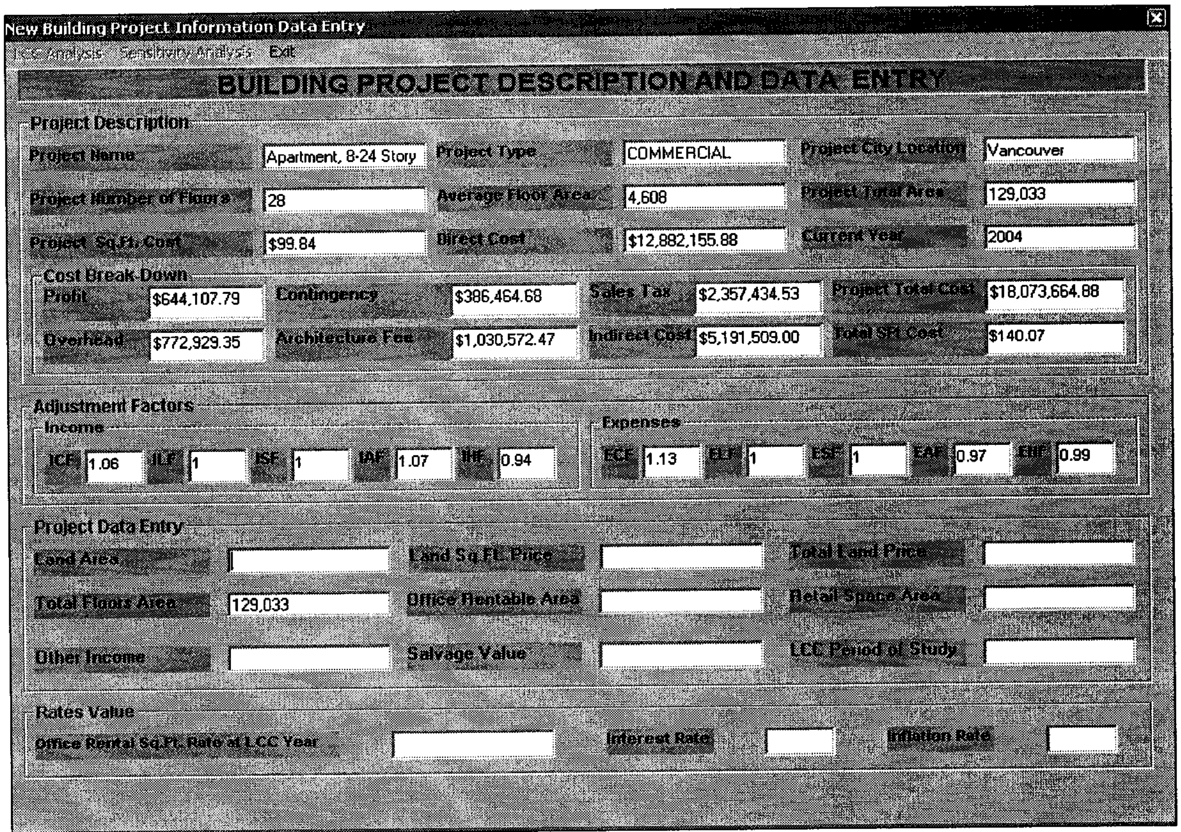


Figure 6.28 Life Cycle Costing Required Data Form

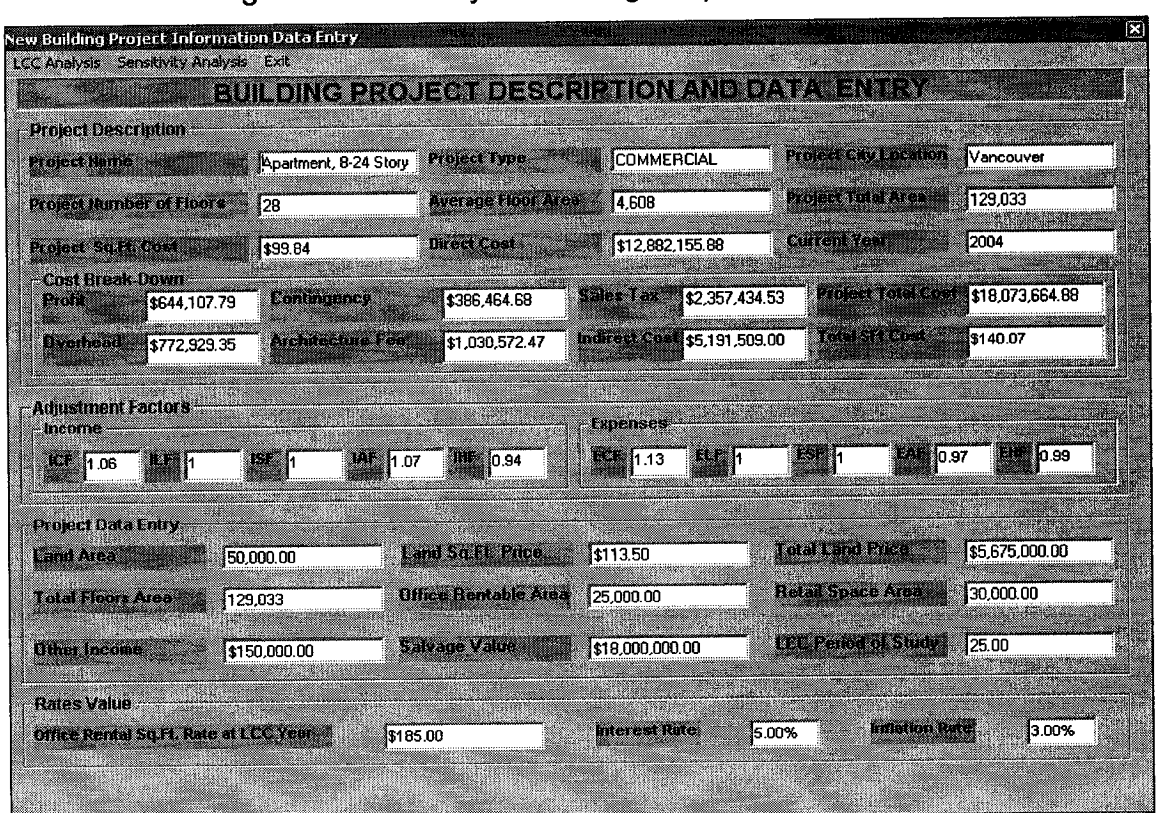


Figure 6.29 LCC's Entered Data

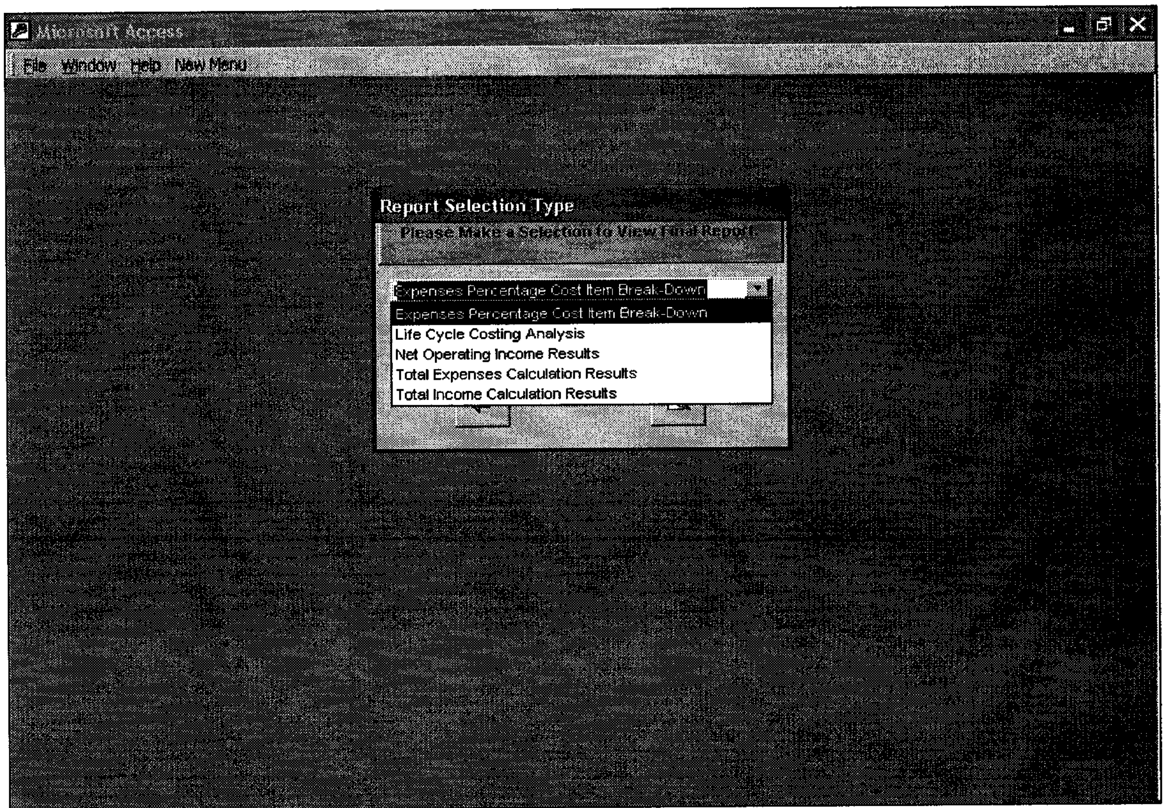


Figure 6.30 Selecting Output Report from the List

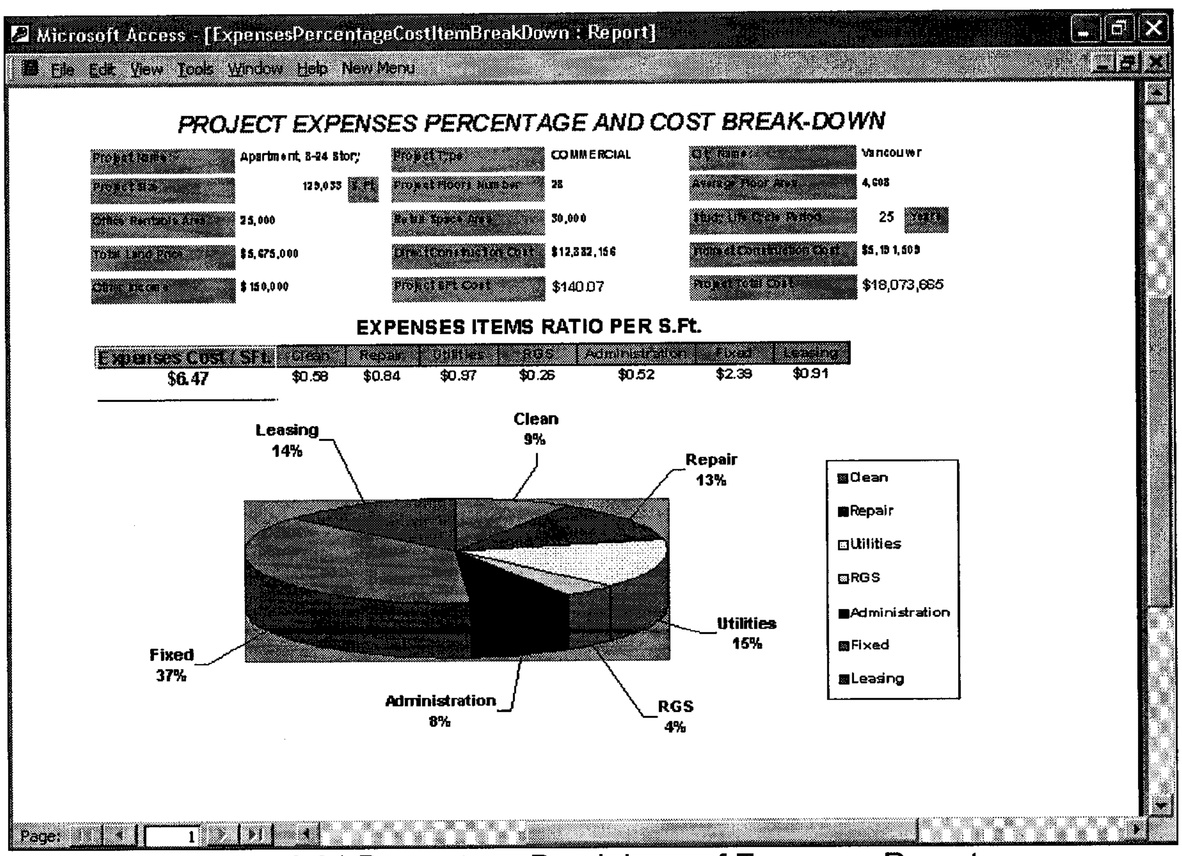
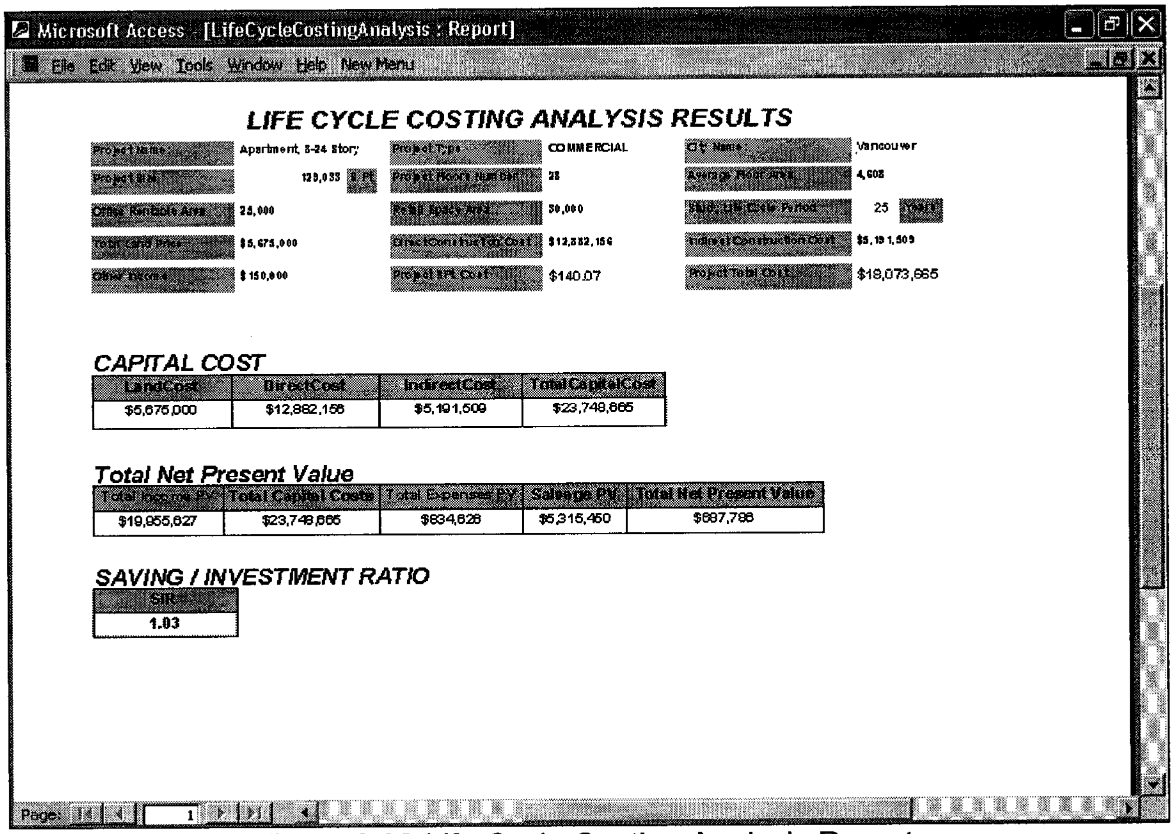


Figure 6.31 Percentage Breakdown of Expenses Report



LandCost	DirectCost	IndirectCost	TotalCapitalCost
$5,675,000	$12,882,156	$5,191,509	$23,748,665

Total Income PV	Total Capital Costs	Total Expenses PV	Salvage PV	Total Net Present Value
$19,955,627	$23,748,665	$834,628	$5,315,450	$687,786

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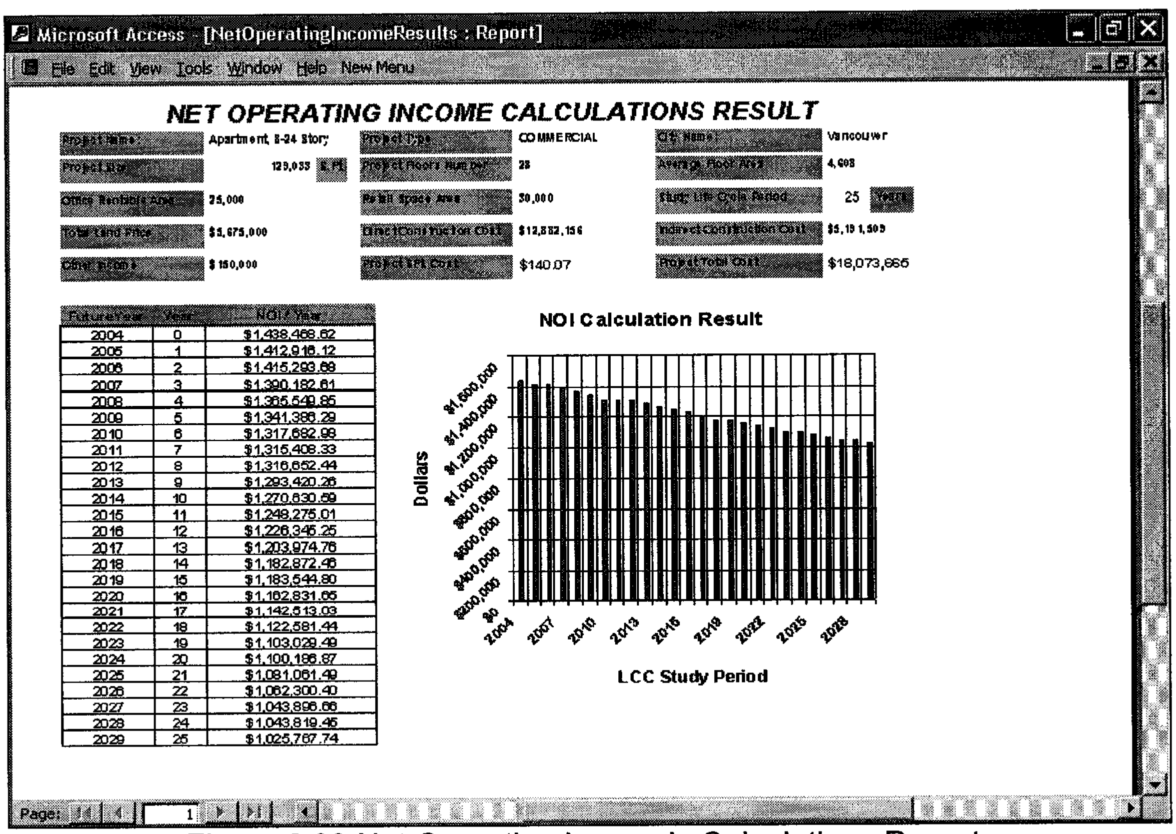
Figure 6.32 Life Cycle Costing Analysis Report



FutureYear	Year	NOI / Year
2004	0	$1,438,468.62
2005	1	$1,412,916.12
2006	2	$1,415,293.68
2007	3	$1,390,182.61
2008	4	$1,365,549.85
2009	5	$1,341,386.29
2010	6	$1,317,682.98
2011	7	$1,315,408.33
2012	8	$1,316,652.44
2013	9	$1,293,420.26
2014	10	$1,270,630.59
2015	11	$1,248,275.01
2016	12	$1,226,346.25
2017	13	$1,203,974.76
2018	14	$1,182,872.46
2019	15	$1,183,544.80
2020	16	$1,162,831.65
2021	17	$1,142,513.03
2022	18	$1,122,581.44
2023	19	$1,103,029.49
2024	20	$1,100,186.87
2025	21	$1,081,061.49
2026	22	$1,062,300.40
2027	23	$1,043,896.66
2028	24	$1,043,819.46
2029	25	$1,025,767.74

Figure 6.33 Net Operating Income's Calculations Report

Microsoft Access - [TotalExpenseCalculationResults : Report]

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PROJECT FORECASTED TOTAL EXPENSE CALCULATION RESULTS

Project Name	Apartment, 8-24 Story	Project Type	COMMERCIAL	City Name	Vancouver
Project Size	129,033 S.Ft	Project Floors Number	28	Average Floor Area	4,608
Office Rentable Area	25,000	Retail Space Area	30,000	Study Life Cycle Period	25 Years
Total Land Price	$5,675,000	Direct Construction Cost	$12,882,156	Indirect Construction Cost	$5,191,509
Other Income	$150,000	Project SFt Cost	$140.07	Project Total Cost	$18,073,665

Total Expense Calculation Results

Future Year	Year	TOEFL Rate	TOEFL / YEAR	TOEFL PV
2004	0	$12	$53,037	$53,037
2005	1	$12	$53,037	$50,512
2006	2	$12	$53,037	$48,106
2007	3	$12	$53,037	$45,816
2008	4	$12	$53,037	$43,634
2009	5	$12	$53,037	$41,556
2010	6	$12	$53,037	$39,577
2011	7	$12	$53,037	$37,693
2012	8	$12	$53,037	$35,898
2013	9	$12	$53,037	$34,188
2014	10	$12	$53,037	$32,560
2015	11	$12	$53,037	$31,010
2016	12	$12	$53,037	$29,533
2017	13	$12	$53,896	$28,582
2018	14	$12	$53,896	$27,221
2019	15	$12	$53,896	$25,925
2020	16	$12	$53,896	$24,690
2021	17	$12	$53,896	$23,515
2022	18	$12	$53,896	$22,395
2023	19	$12	$53,896	$21,328
2024	20	$12	$53,896	$20,313
2025	21	$12	$53,896	$19,345
2026	22	$12	$53,896	$18,424
2027	23	$12	$53,896	$17,547
2028	24	$12	$53,896	$16,711
2029	25	$12	$53,896	$15,916
2030	26	$12	$53,896	$15,158
2031	27	$12	$53,896	$14,436

Page: 1

Figure 6.34 Forecasted Total Expenses Report

Microsoft Access - [TotalIncomeCalculationResults : Report]

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PROJECT FORECASTED TOTAL INCOME CALCULATION RESULTS

Project Name	Apartment, 8-24 Story	Project Type	COMMERCIAL	City Name	Vancouver
Project Size	129,033 S.Ft	Project Floors Number	28	Average Floor Area	4,608
Office Rentable Area	25,000	Retail Space Area	30,000	Study Life Cycle Period	25 Years
Total Land Price	$5,675,000	Direct Construction Cost	$12,882,156	Indirect Construction Cost	$5,191,509
Other Income	$150,000	Project SFt Cost	$140.07	Project Total Cost	$18,073,665

Total Income Calculation Results

Future Year	Year	Rent Rate	Rent Income/Year	Retail Rate	Retail Income/Year	Other Income	Total Income / Year	Total Income PV
2004	0	$30	$741,506	$20	$600,000	$150,000	$1,491,506	$1,491,506
2005	1	$29	$727,382	$20	$588,571	$150,000	$1,465,953	$1,396,146
2006	2	$30	$740,970	$19	$577,361	$150,000	$1,468,331	$1,331,819
2007	3	$29	$726,857	$19	$566,363	$150,000	$1,443,220	$1,246,708
2008	4	$29	$713,012	$19	$555,575	$150,000	$1,418,587	$1,167,075
2009	5	$28	$699,431	$18	$544,993	$150,000	$1,394,424	$1,092,567
2010	6	$27	$686,108	$18	$534,612	$150,000	$1,370,720	$1,022,853
2011	7	$27	$673,039	$18	$545,406	$150,000	$1,368,446	$972,529
2012	8	$27	$684,672	$18	$535,018	$150,000	$1,369,690	$927,060
2013	9	$27	$671,631	$17	$524,827	$150,000	$1,346,458	$867,939
2014	10	$26	$658,838	$17	$514,830	$150,000	$1,323,668	$812,617
2015	11	$26	$646,289	$17	$505,024	$150,000	$1,301,312	$760,850
2016	12	$25	$633,978	$17	$495,404	$150,000	$1,279,383	$712,408
2017	13	$25	$621,903	$16	$485,968	$150,000	$1,257,870	$667,076
2018	14	$24	$610,057	$16	$476,711	$150,000	$1,236,768	$624,652
2019	15	$25	$619,809	$16	$467,631	$150,000	$1,237,441	$595,230
2020	16	$24	$608,003	$15	$458,724	$150,000	$1,216,727	$557,397
2021	17	$24	$596,422	$15	$449,986	$150,000	$1,196,409	$521,989
2022	18	$23	$585,062	$15	$441,415	$150,000	$1,176,477	$488,851
2023	19	$23	$573,918	$14	$433,007	$150,000	$1,156,925	$457,835
2024	20	$23	$562,986	$15	$441,096	$150,000	$1,154,083	$434,962
2025	21	$22	$552,263	$14	$432,695	$150,000	$1,134,957	$407,384
2026	22	$22	$541,743	$14	$424,453	$150,000	$1,116,196	$381,572
2027	23	$21	$531,424	$14	$416,368	$150,000	$1,097,792	$357,410
2028	24	$22	$539,278	$14	$408,437	$150,000	$1,097,715	$340,366
2029	25	$21	$529,006	$13	$400,657	$150,000	$1,079,663	$318,828

Page: 1

Figure 6.35 Forecasted Total Income Report

Naturally we could apply the sensitivity analysis method to identify the most sensitive parameters so that suitable measures could be taken as explained in previous chapters, yet we are not going to be able to conduct this analysis on the actual project.

6.3 Forecasting the Costs Based on Size Entry

The same cost data of the actual project used in the previous section is used to validate the system using the linear regression equations based on size entry. To start, select "Use Forecasting Equations" and "Based on Size Entry" from the main gate as shown in Figure 6.36. We then have to make a group of selections that includes the area, exterior wall type, and framing type as seen in Figure 6.37. Directly the system asks to enter the area that is of 129,095 as shown in Figure 6.38. Once the area is entered, the system forecasts the cost based on

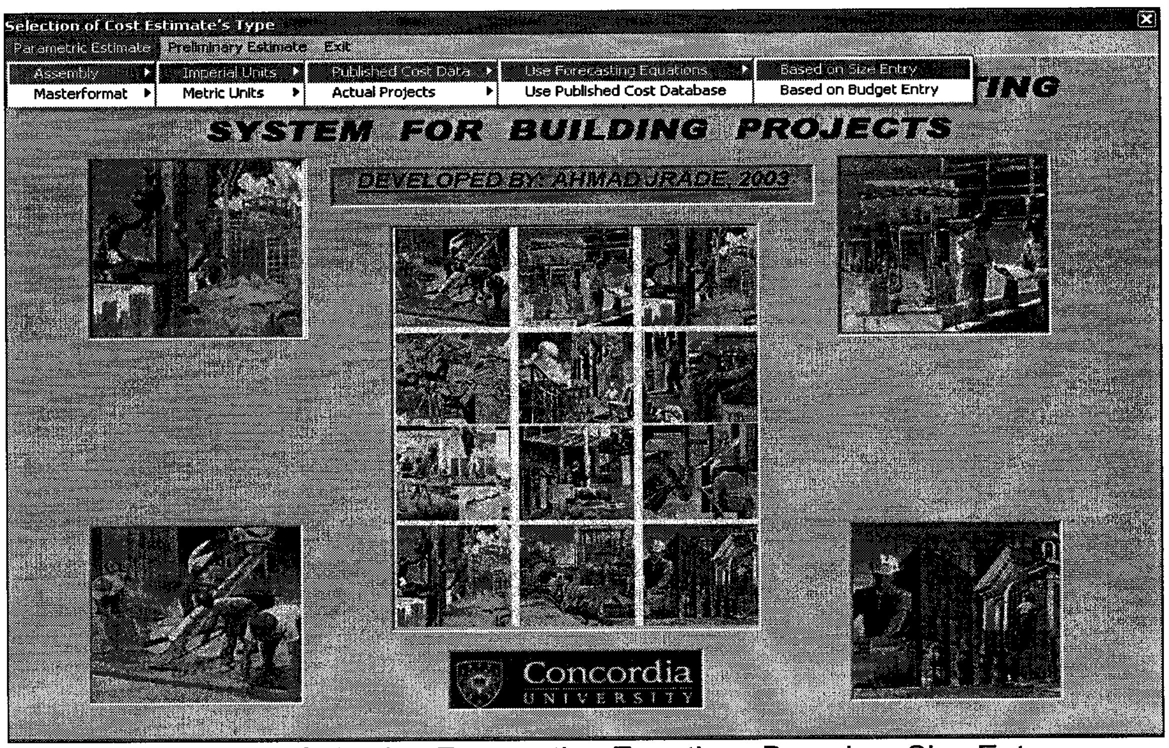

Figure 6.36 Selecting Forecasting Equations Based on Size Entry

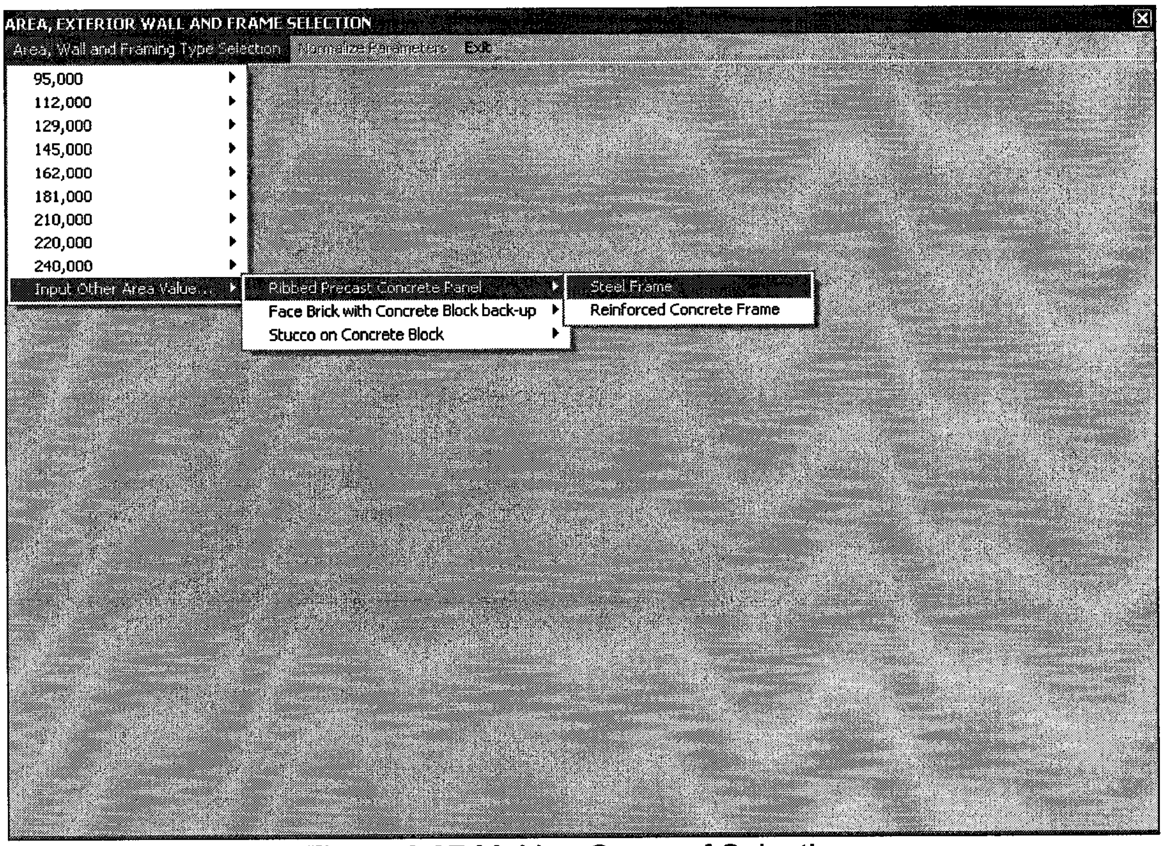

Figure 6.37 Making Group of Selections

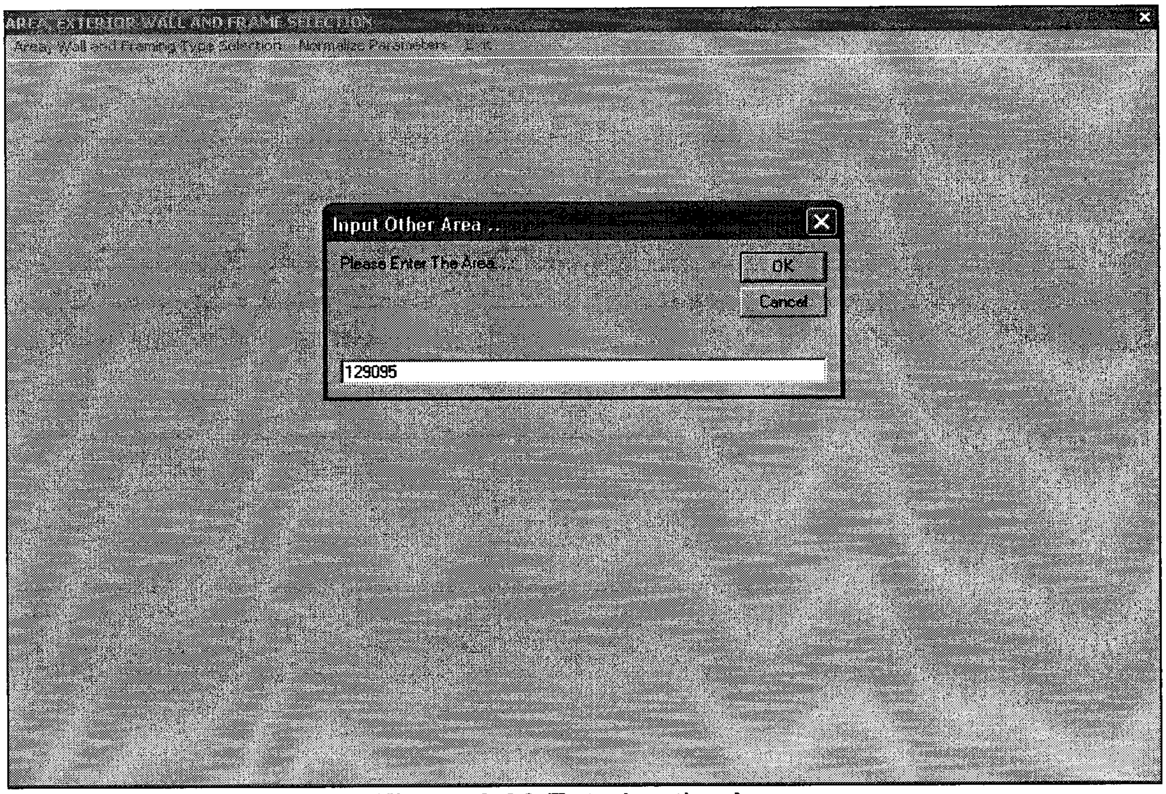

Figure 6.38 Entering the Area

the value of 129,095 using the linear regression equations mentioned in chapter Four paragraph 4.8.1. It provides three different formats similar to Figures 6.15 to 6.17. Certainly, the system searches for the best-fitted 3D-CAD drawing

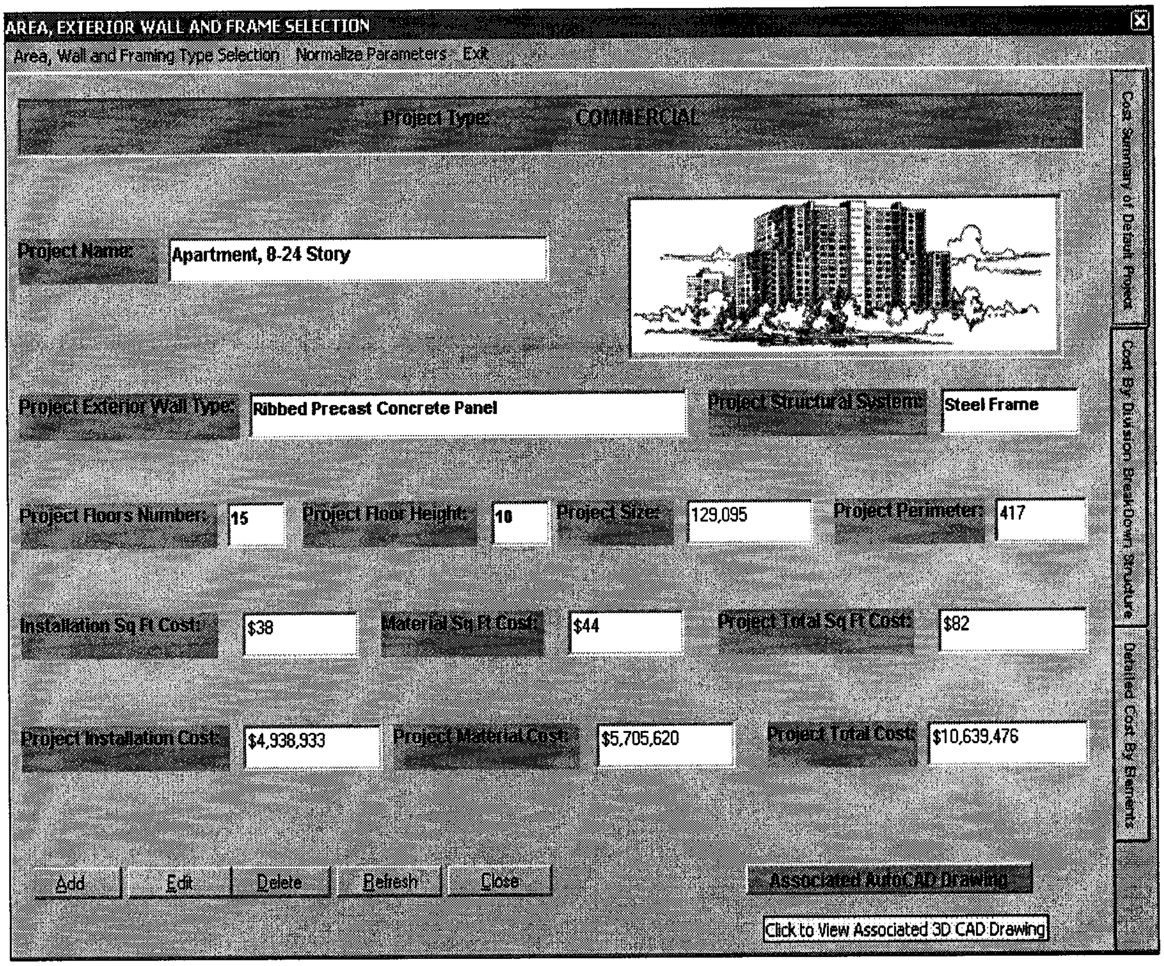

Figure 6.39 Summarized Format of the Forecasted Costs

from the database that has an area close to the one entered by simply clicking on the “Associated AutoCAD Drawing” button as seen in Figure 6.39. The system provides us with a drawing that has a total area of 129,500 ft^2 and a perimeter of 548.09 as shown in Figures 6.40 to 6.42. Since there is an area’s difference of 405 ft^2 and a perimeter’s difference of 131 ft between the actual, entered and forecasted ones, we modified the drawing so its parameters approached those of the actual project as seen in Figures 6.43 to 6.45.

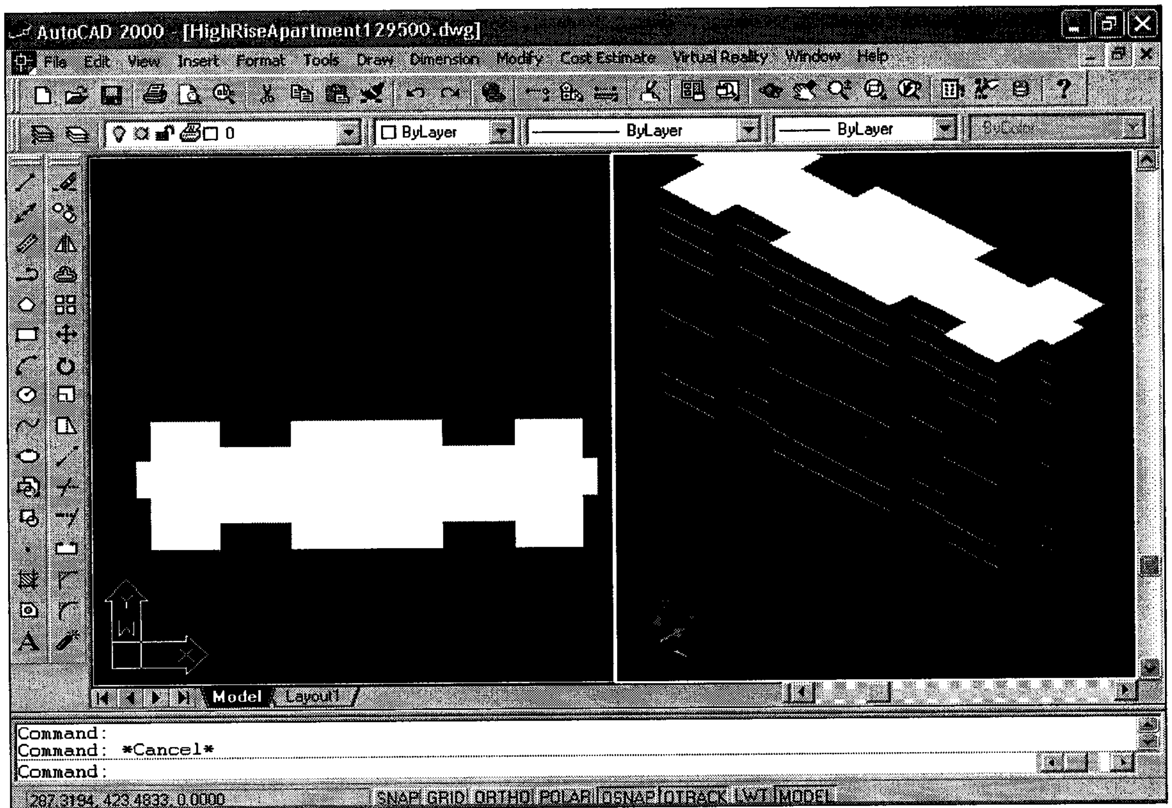

Figure 6.40 3D-CAD Drawing Provided by the System

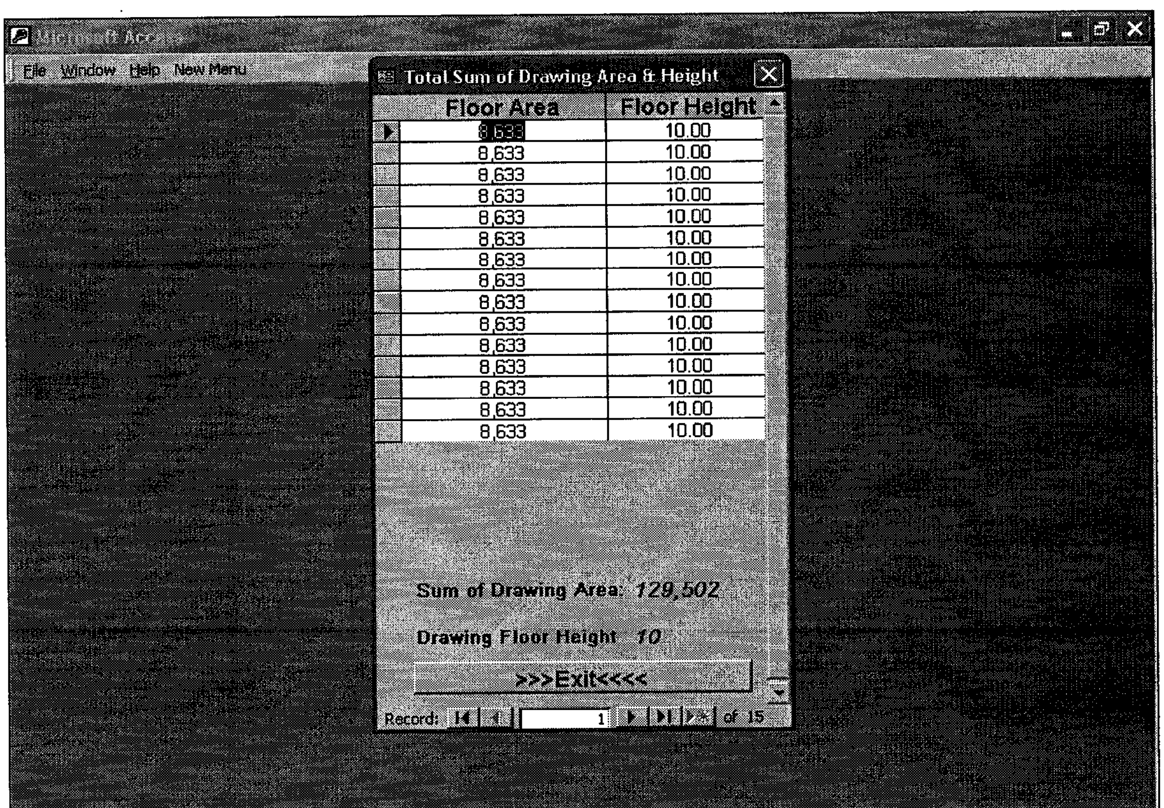

Figure 6.41 Total Floors Area of the Provided Drawing

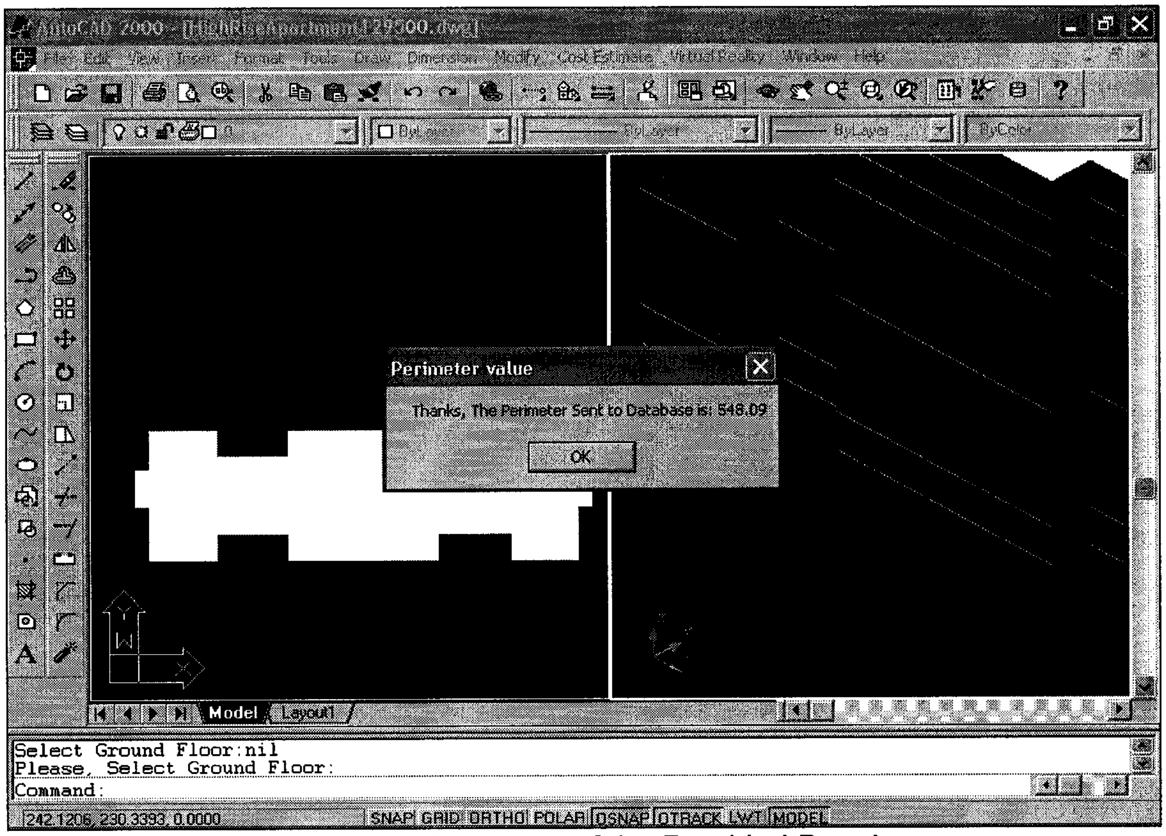

Figure 6.42 Perimeter of the Provided Drawing

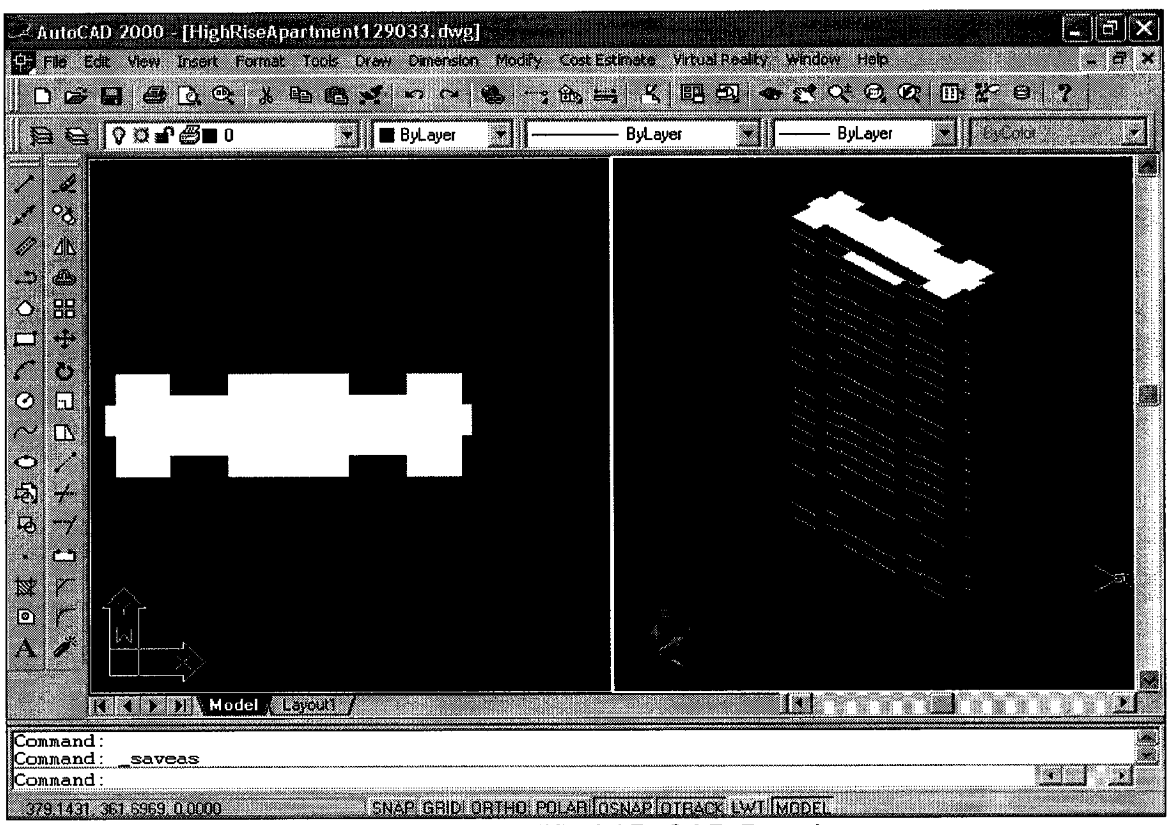

Figure 6.43 Modified 3D-CAD Drawing

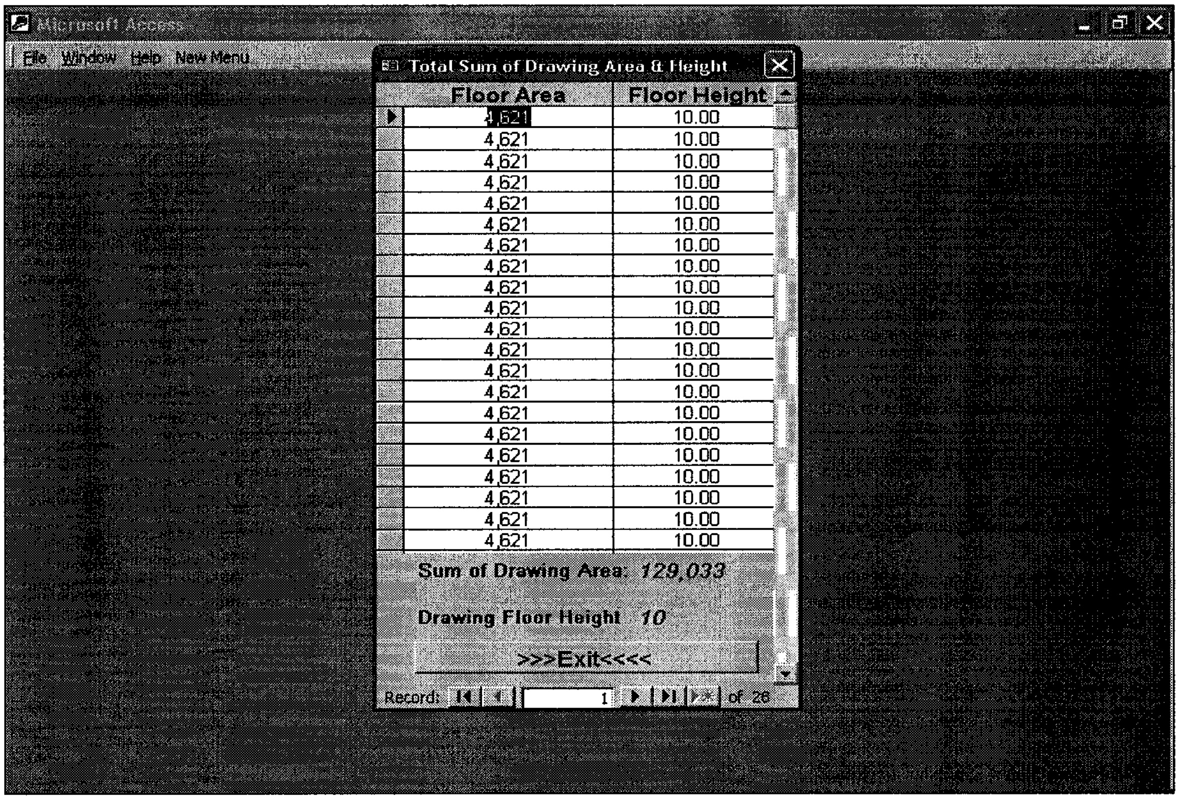

Figure 6.44 Total Floors Area of Modified the Drawing

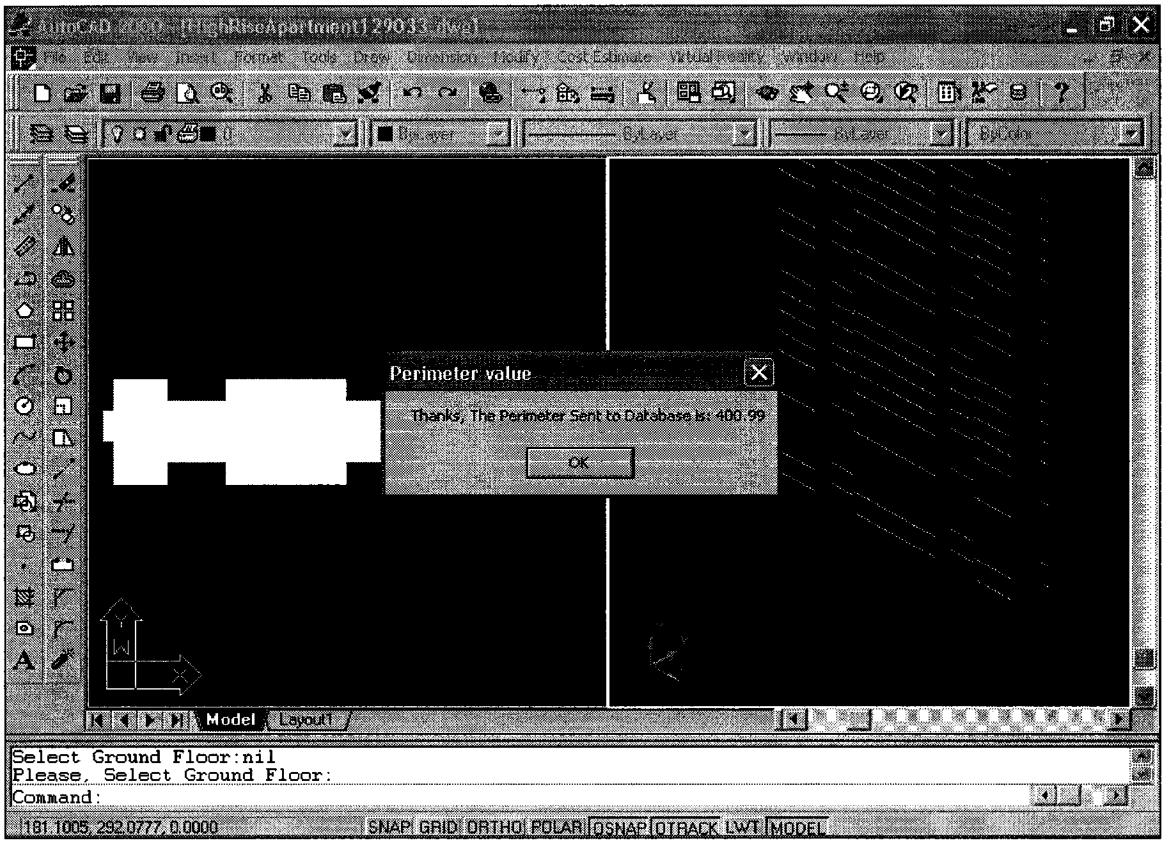

Figure 6.45 Perimeter of the Modified 3D-CAD Drawing

Afterwards, adjustments have to be made based on the new parameters extracted from the drawing as mentioned earlier in previous paragraphs. This is illustrated in Figure 6.46. The linear regression equations are based on the National Average cost for year 2000, and since we have adjusted the direct construction cost of the actual project from year 1996 to 2000 we considered the

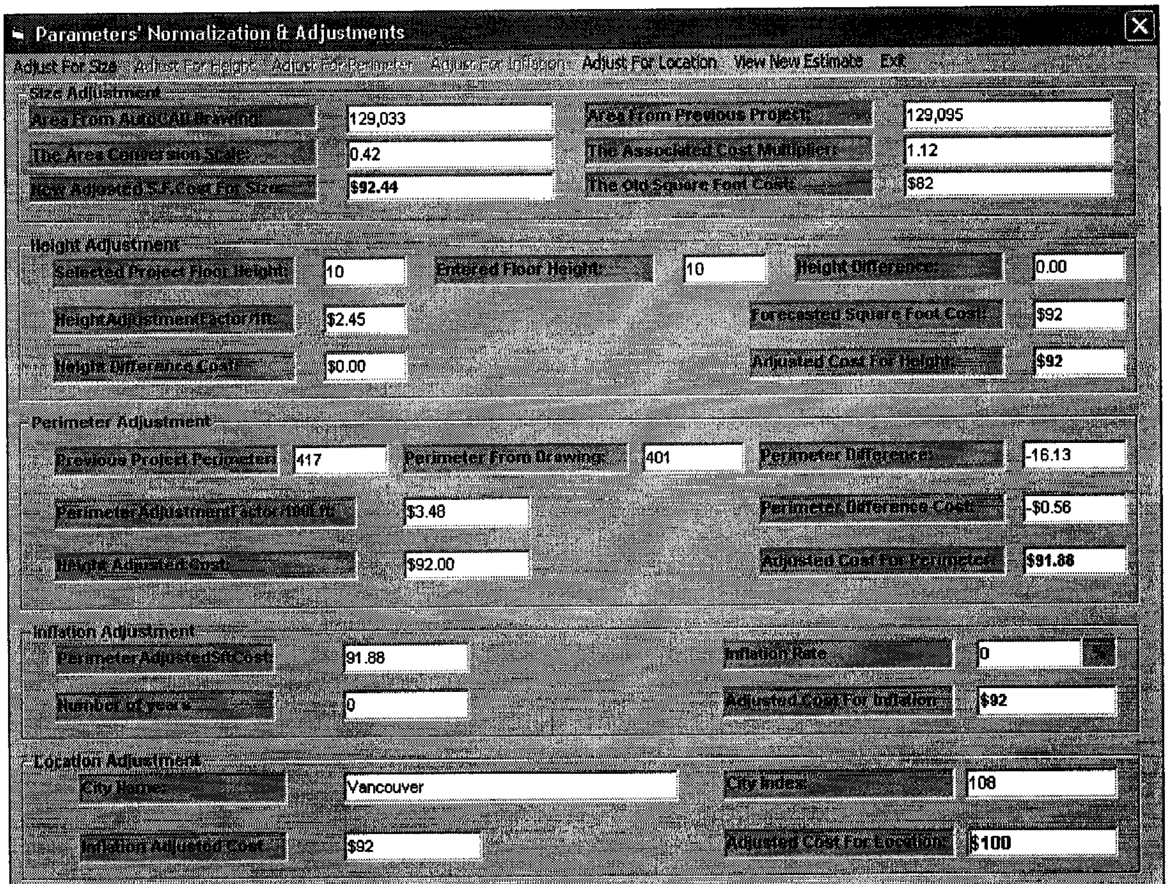

Figure 6.46 the New Adjusted Square Foot Cost

inflation rate and number of years as zero. However an adjustment for location is made to have the final square foot cost adjusted for the city of Vancouver, which gives us a value of $\$100/ft^2$. Based on this value, the system forecasts the new estimate and provides us with four different formats, Figures 6.47 and 6.48 illustrate two of them.

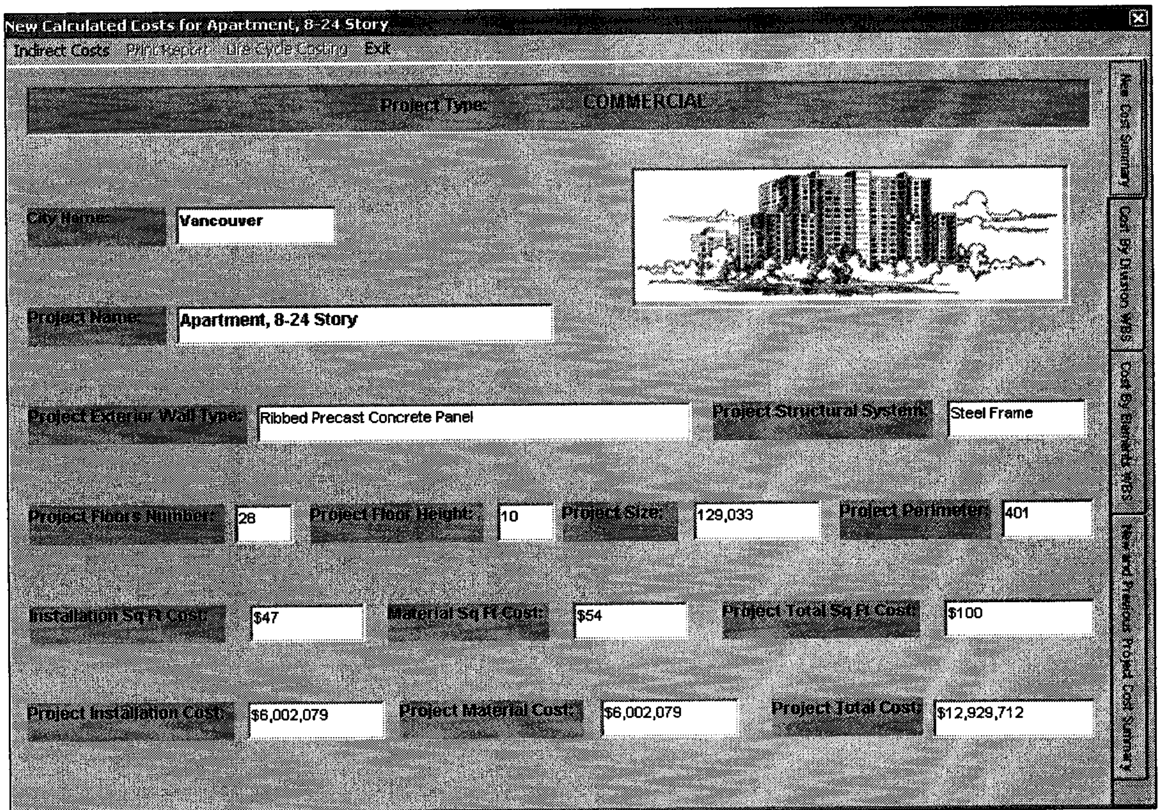

Figure 6.47 Summarized Format of the New Forecasted Costs

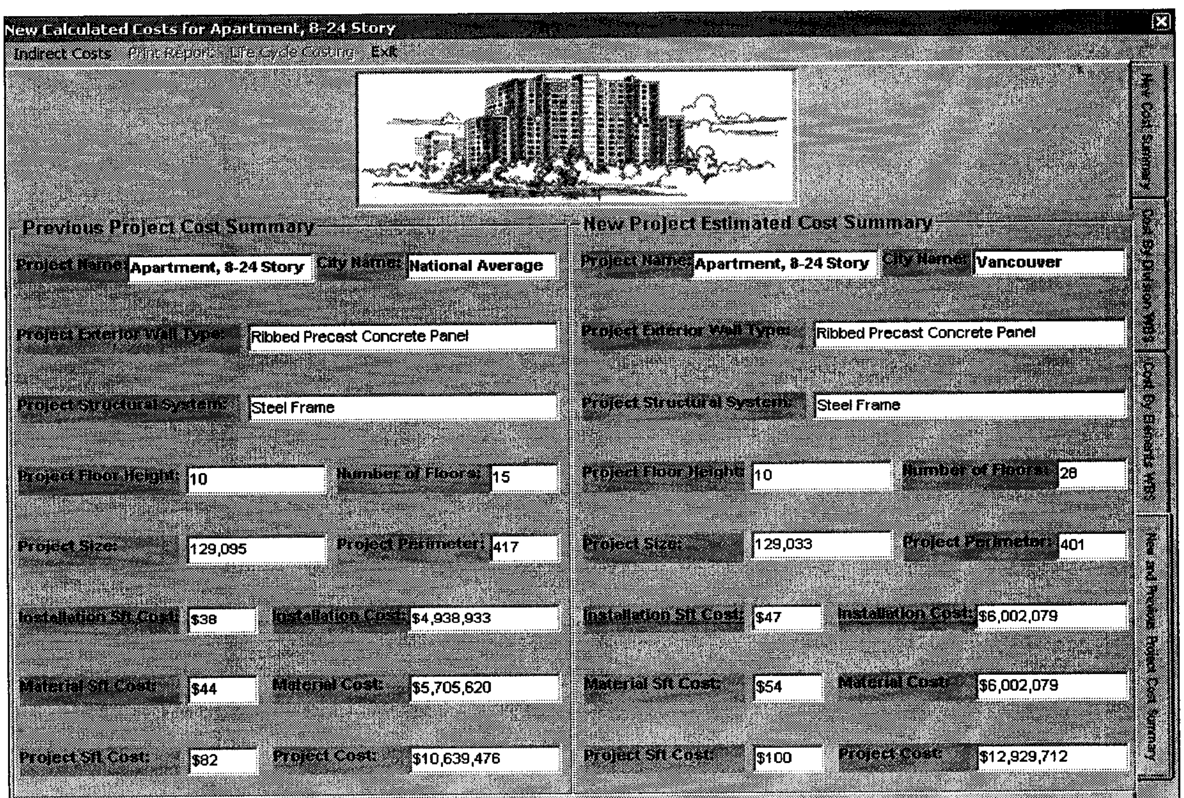

Figure 6.48 Previous and New Forecasted Costs

As seen in Figure 6.47 the new forecasted construction cost of the modified drawing is $12,929,712 for the year 2000, whereas the value of the actual project at the same year is $11,541,334. There is a difference of +$1,388,378 which corresponds to +12.03%, routed on AACE International Classification in Table 2.1. This is a very good accuracy level for this type of cost estimate. Adding the indirect costs to the forecasted one, the system provides a total cost of $18,140,386 compared to $20,244,163 for the actual project for the year 2000. This gives a difference of -$2,103,777, matching a –11.59%. Indeed, we can forecast the running costs of the project by following the same procedures taken in the previous paragraph, which can be referred to Figures 6.28 to 6.35.

6.4 Forecasting the Costs Based on Budget Entry

To use this estimating tool we have to adjust the actual direct construction cost from year 1996 to year 2004. The reason for doing so is that, in this tool, the system brings back the budget-entered value to year 2000 and National Average Cost because the linear regression equations derived in chapter Four, paragraph 4.8.2 were based on this type of cost for the mentioned year. Thus, the actual direct construction cost of $10,254,326 is adjusted for year 2004 by considering an inflation rate of 3%, and accordingly the new value is $12,989,873. From the main gate illustrated in Figure 6.49, we select "Using Forecasting Equations" and "Based on Budget Entry" to activate the correlated module. Instantaneously, the system asks us to enter the budget value as shown in Figure 6.50.

Figure 6.49 Selecting Forecasting Equations Based on Budget Entry

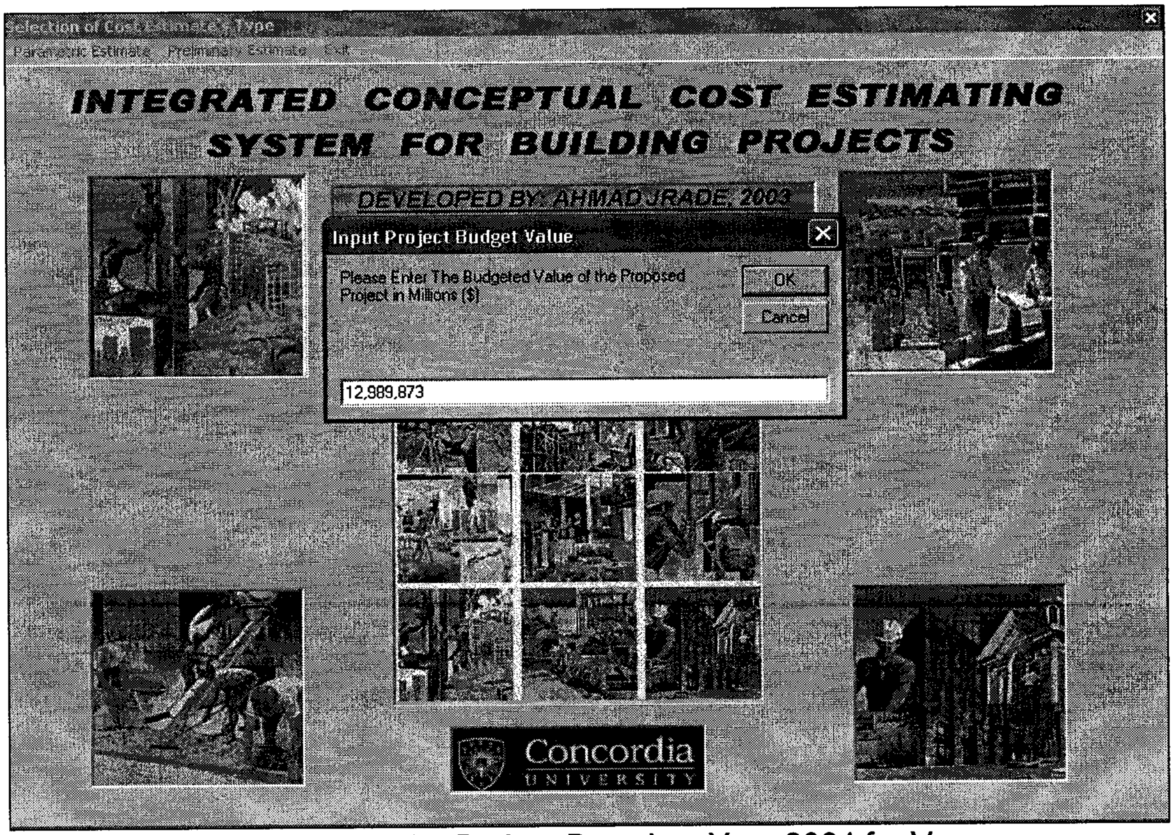

Figure 6.50 Entering the Budget Based on Year 2004 for Vancouver

After confirming the value entered and after identifying that this value comprises direct construction costs only, the system prompts for inputting the indirect percentages as seen in Figure 6.51.

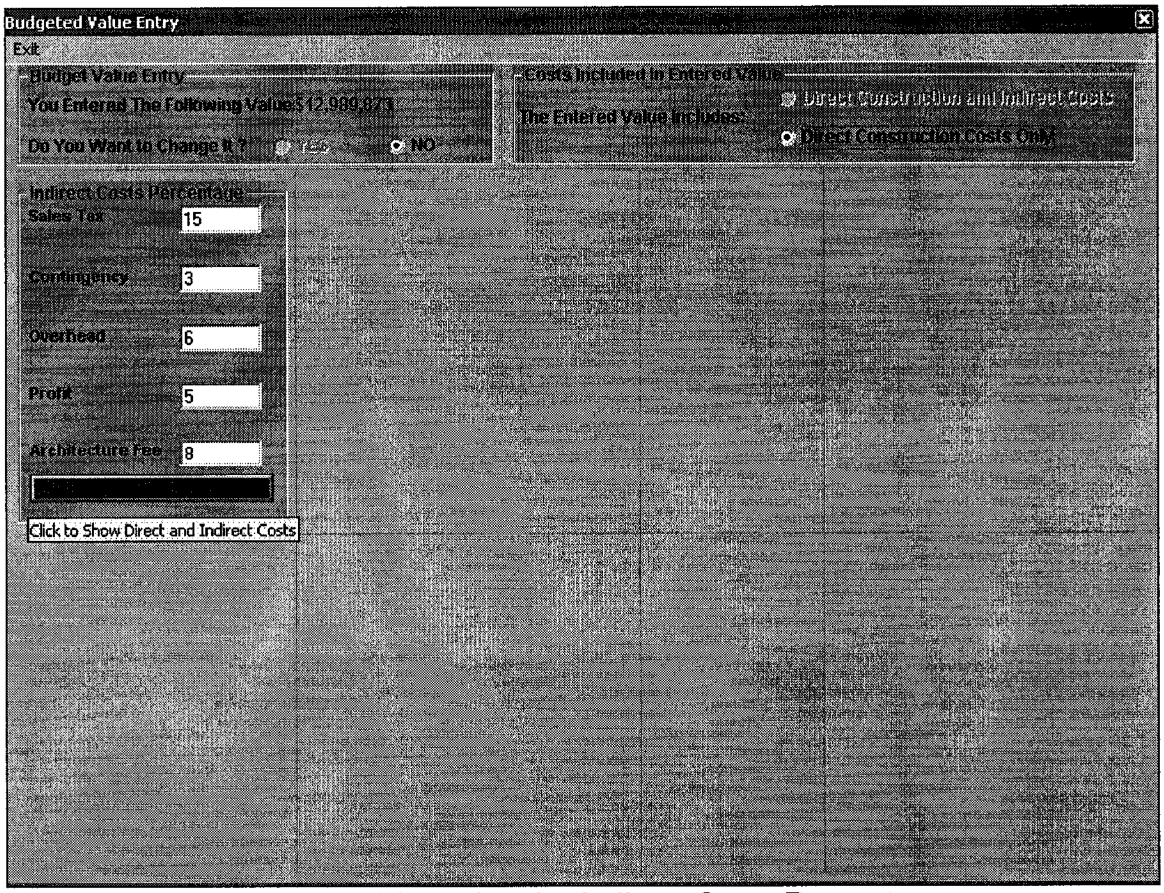

Figure 6.51 Inputting the Indirect Costs Percentage

As soon as the indirect percentages are entered, the system calculates the indirect costs using equations [4.17] to [4.19] derived in chapter Four and paragraph 4.8.2 as exemplified in Figure 6.52. Furthermore, the system needs to identify the city where the project is located, in this case "Vancouver", and to change the default value of the city location factor inherited into it, as seen in Figure 6.53. The reason for doing so is to bring the entered value to National Average cost and accordingly to calculate the direct and indirect costs using the equation [4.20] as demonstrated in Figure 6.54.

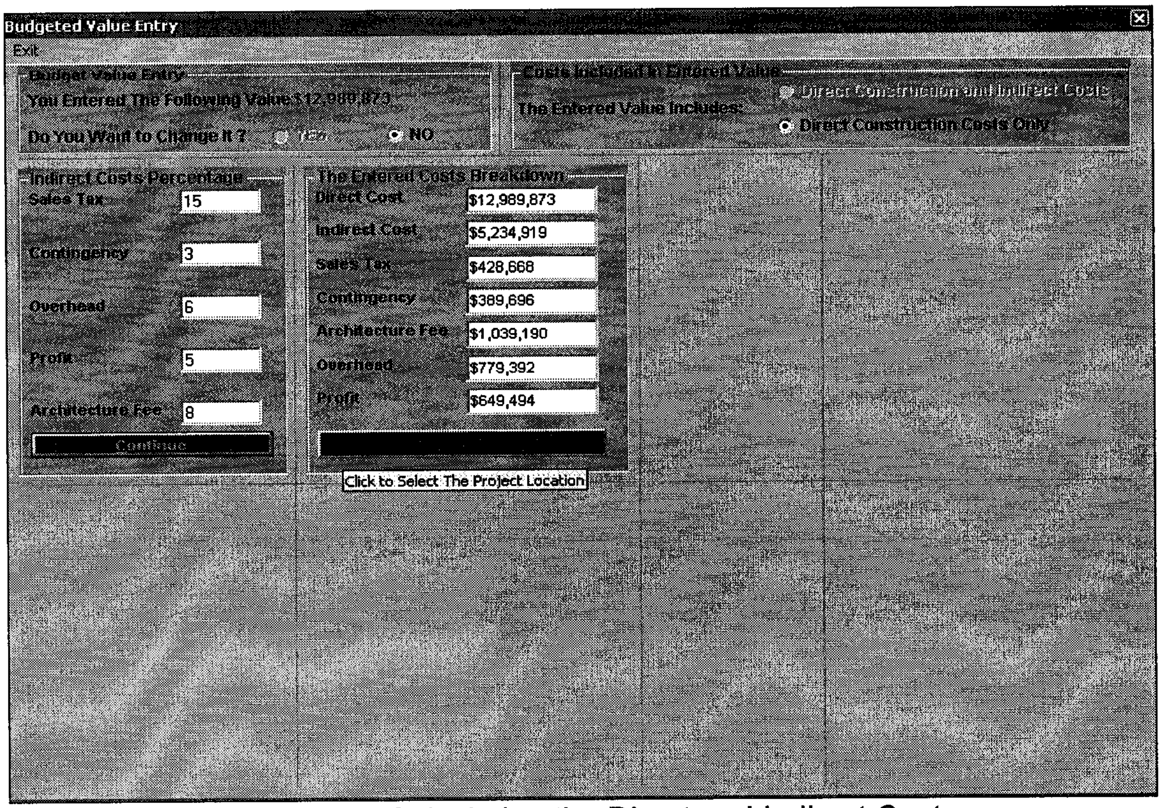

Figure 6.52 Calculating the Direct and Indirect Costs

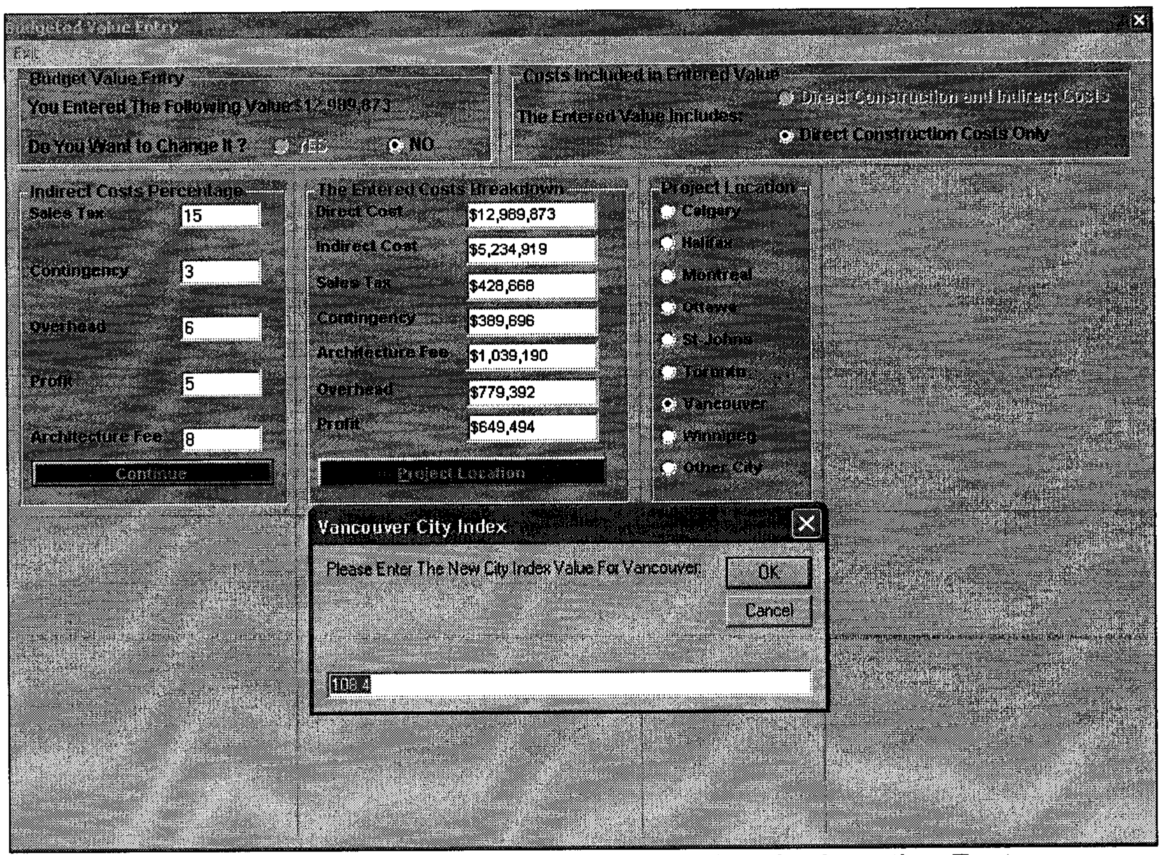

Figure 6.53 Identifying the City and Entering the Location Factor

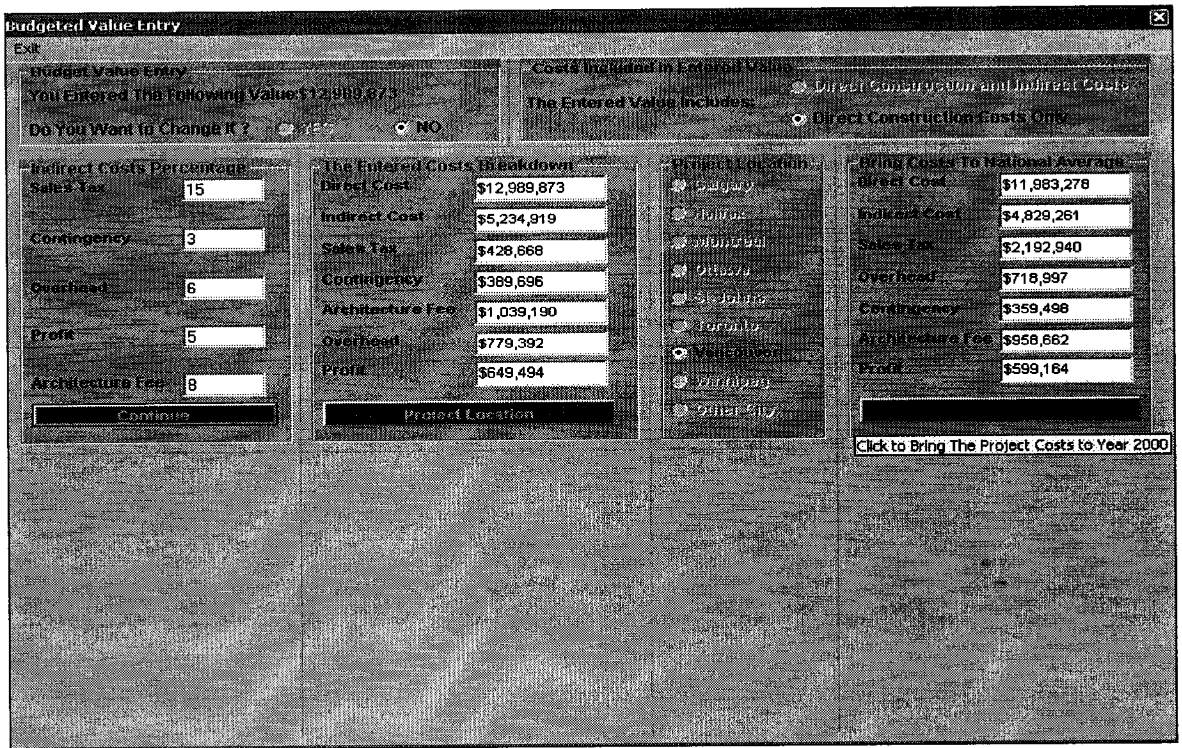

Figure 6.54 Bringing the Project Costs to National Average Value

The new computed value has to be brought to year 2000 using the equation [4.21]. For this reason the system needs the inflation rate, which is 3% in our case. The system automatically identifies the number of years by reading the current year from the computer's date and hence calculates the value of "n" and then adjusts the costs to year 2000 as shown in Figure 6.55. At this stage, the system needs to know the project's category, which is "Commercial", and after that to know if to run the DSS or manually select the project type. We select to run the DSS as seen in Figure 6.56. Before running the DSS, we select the "Narrow" rule type, and, based on this selection, the DSS provides two projects the direct costs of which are compatible with the entered one. One of these projects is "Apartment, 8-24 Story" that has "Ribbed Precast Concrete Panel" as Exterior Wall Type and " Steel" as Framing Type. Figures 6.57 and 6.58 show this matter.

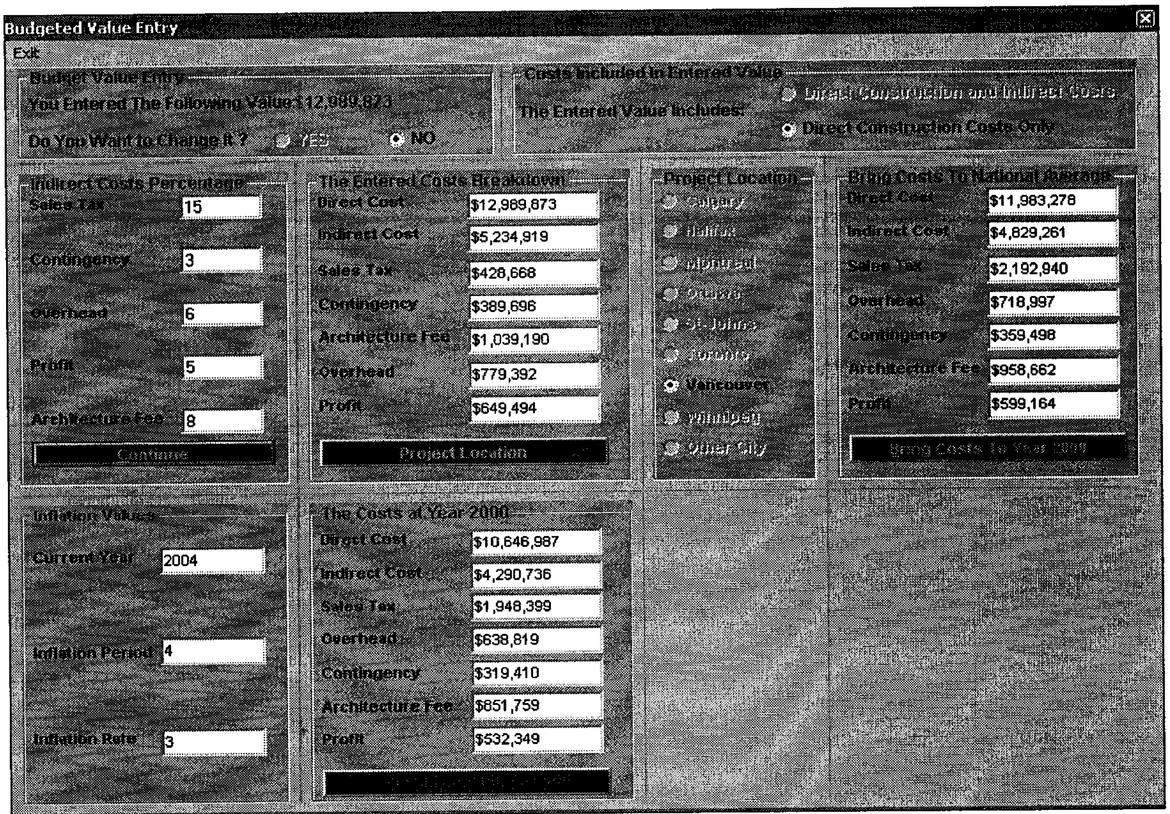

Figure 6.55 Bringing Costs to Year 2000

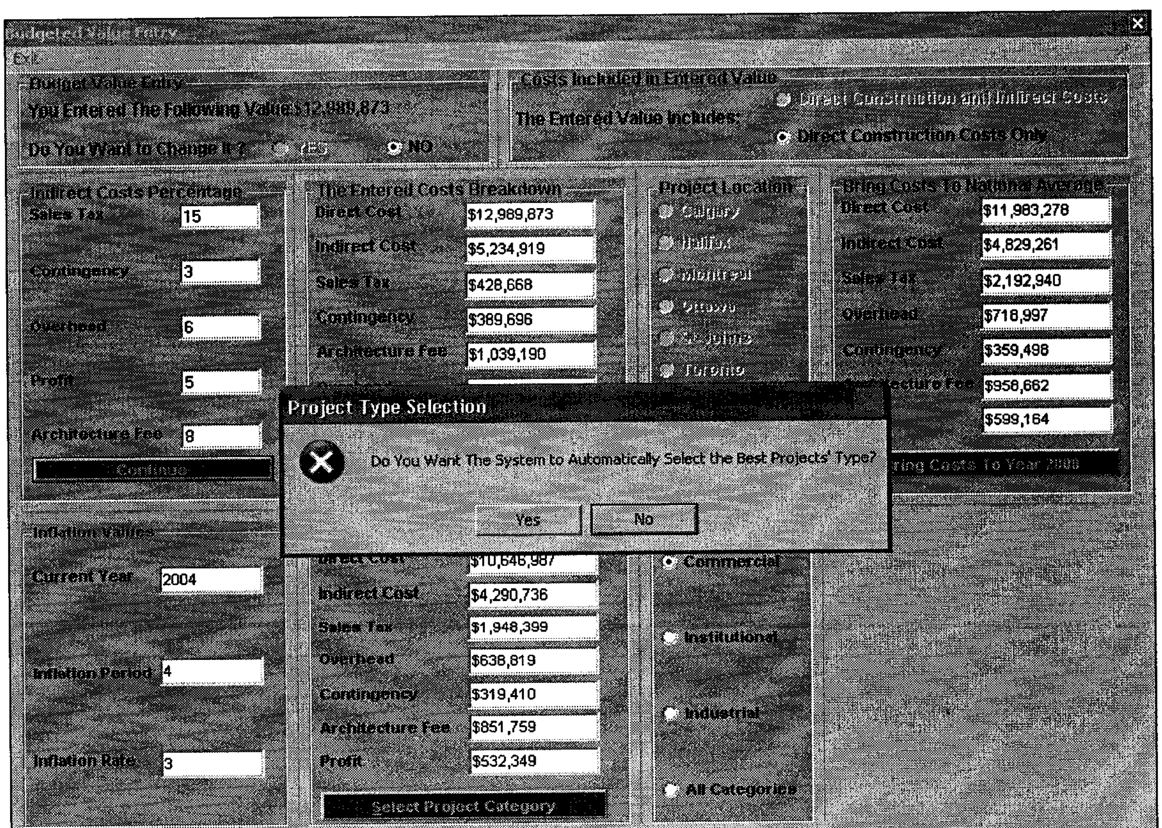

Figure 6.56 Identify the Project's Category and to Run the DSS

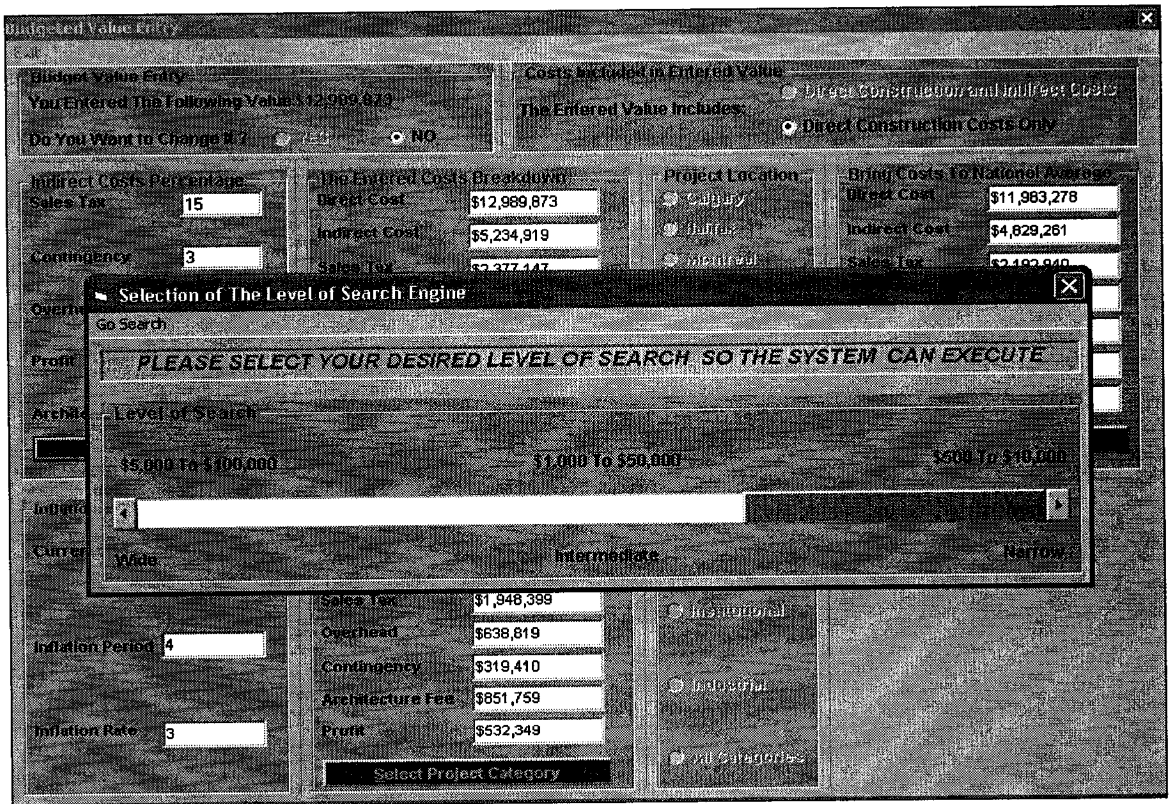

Figure 6.57 Using The DSS's "Narrow" Rule Class

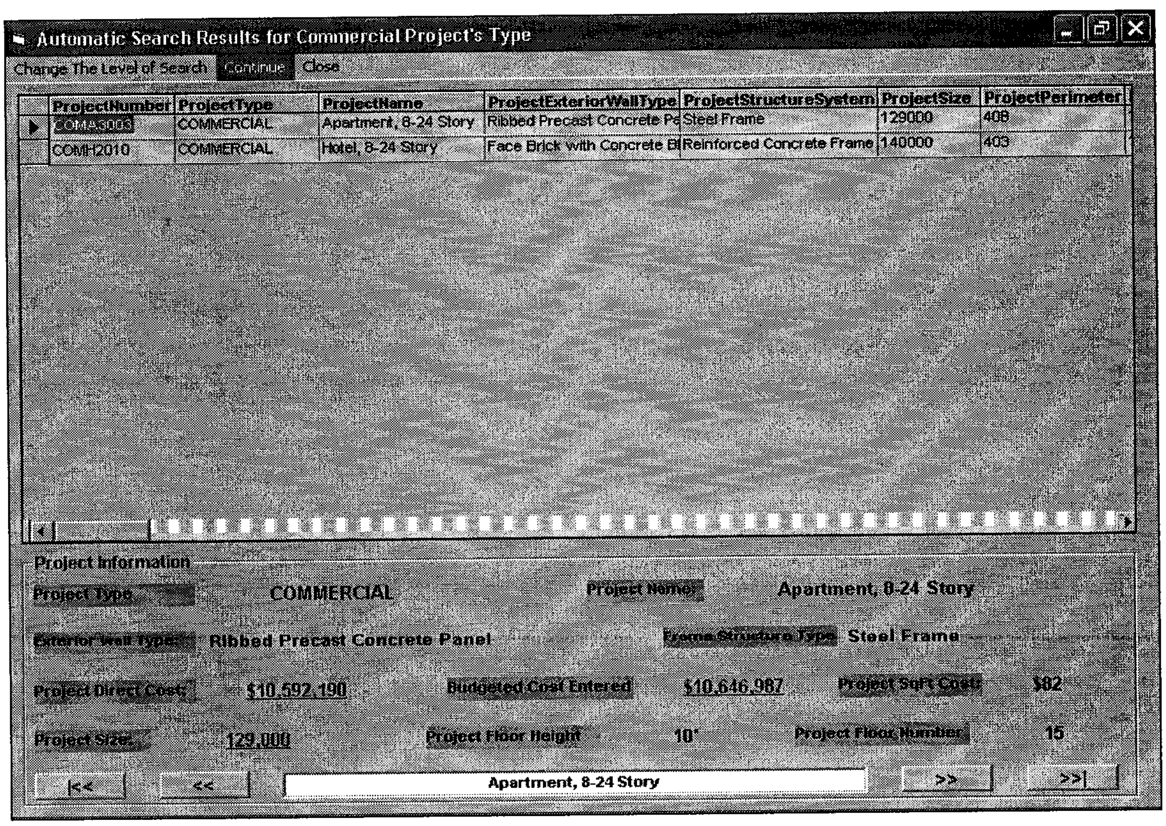

Figure 6.58 List of Findings Supplied by the DSS

Once the "Continue" top menu is clicked on, the system, basing its calculations on the value of $10,646,987, forecasts the area, which is 129,003 ft^2 as seen in Figure 6.59. This value is different from the actual one by -92 ft^2, which correspond to –0.071%.

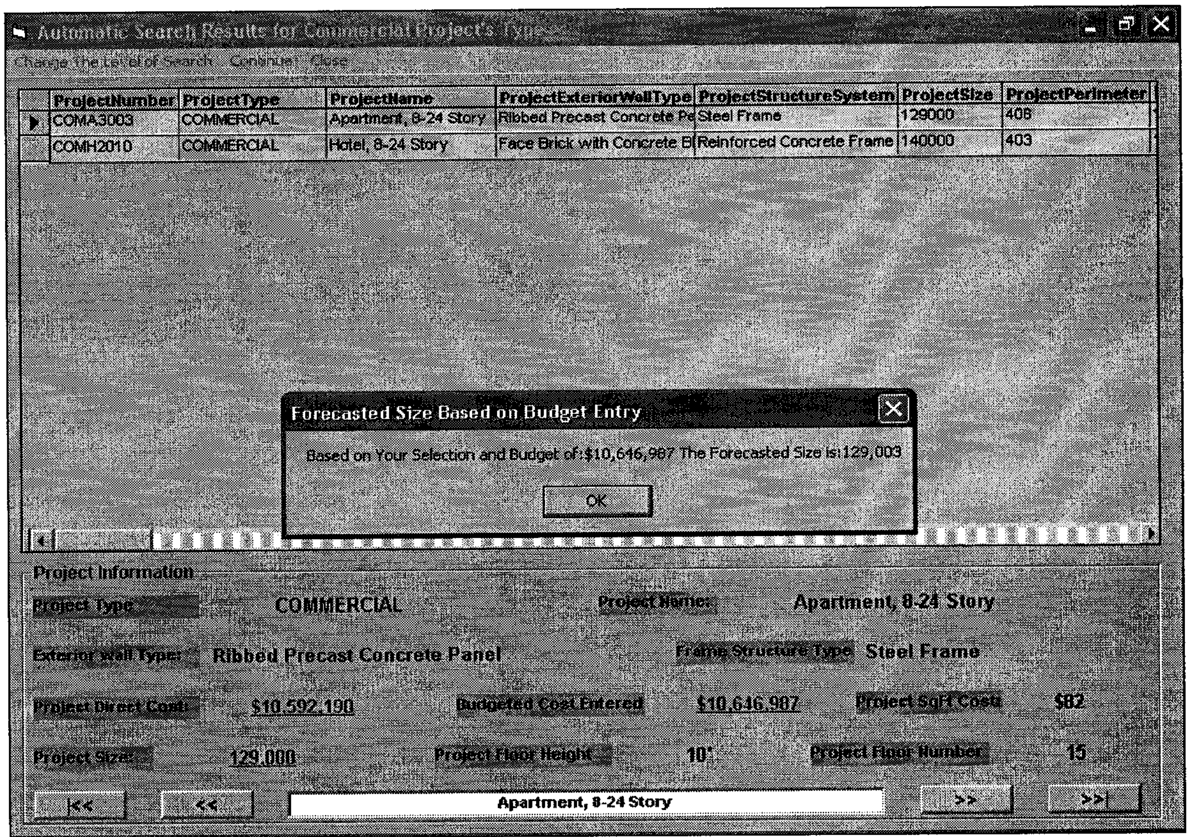

Figure 6.59 Forecasted Area Based on the Entered Budget

Once the "OK" button is clicked, the system forecasts all the components of the estimate and supplies them in three different formats. Figure 6.60 shows a summarized one. Hitting the "Associated AutoCAD Drawing" button in that form runs the DSS in an attempt to find a 3D-CAD drawing that has the closest area to the forecasted one, the selected drawing of which has an area of 129,500 ft^2 and a perimeter of 548.09 ft is shown in Figure 6.61. This drawing is modified in a way such that its area is 129,033 ft^2 and perimeter is 401ft., afterward these

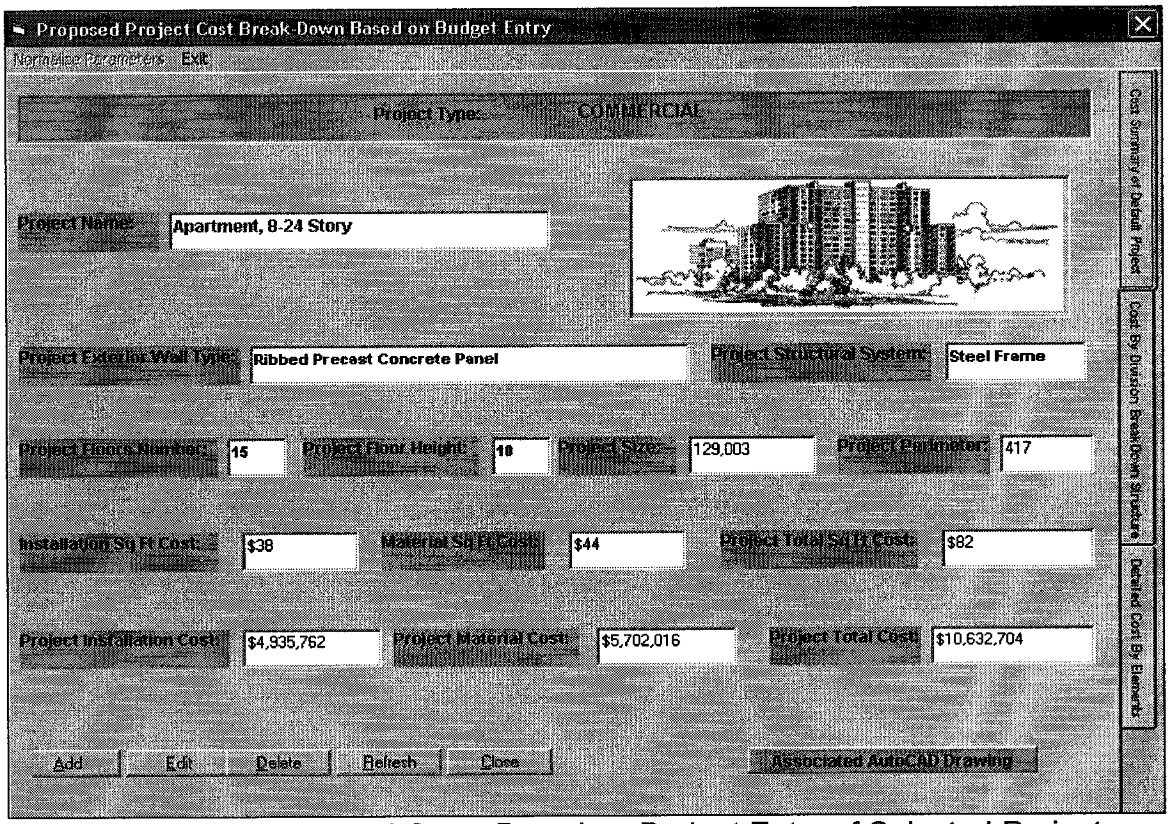

Figure 6.60 Forecasted Costs Based on Budget Entry of Selected Project

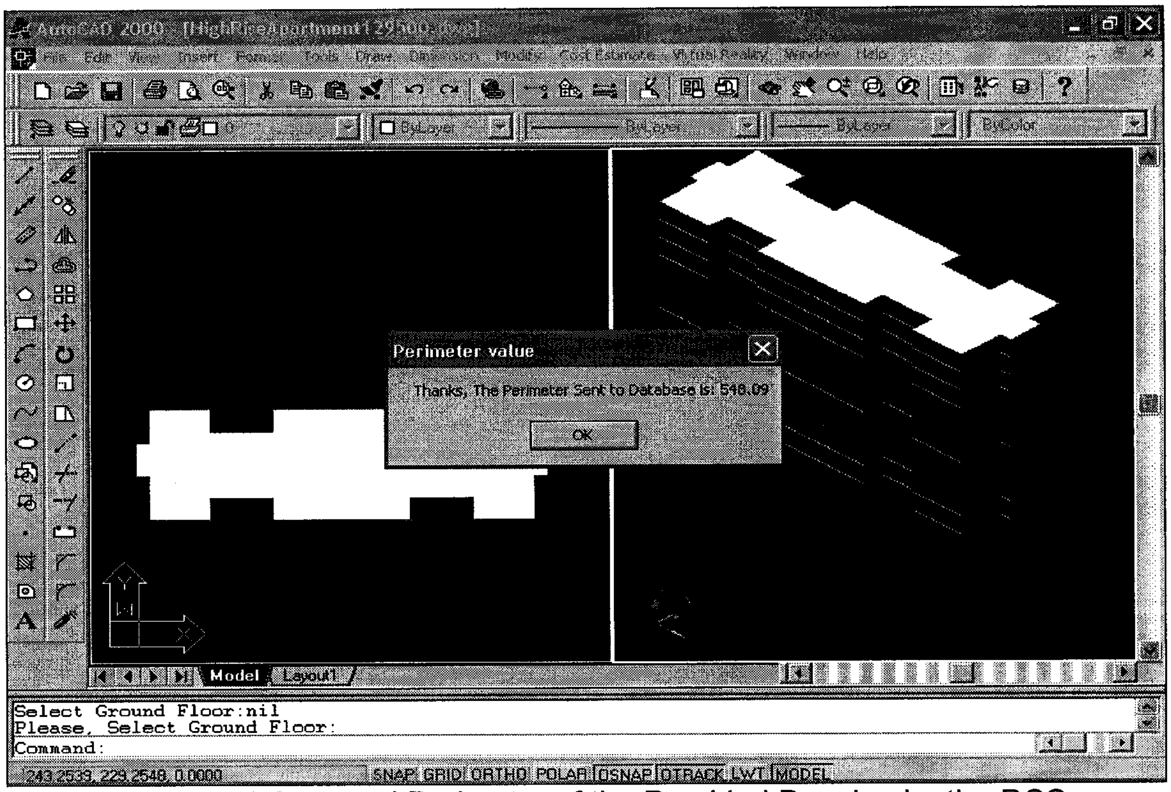

Figure 6.61 Area and Perimeter of the Provided Drawing by the DSS

parameters are sent to the external database and all required adjustment are automatically executed by the system as seen in Figure 6.62. At the end, a new cost estimate is generated and provided by the system in four different formats, Figure 6.63 illustrates one of these formats. Moreover, the system provides four different formats of output reports to select from following the input of the indirect percentages; Figure 6.64 exemplifies a summarized report.

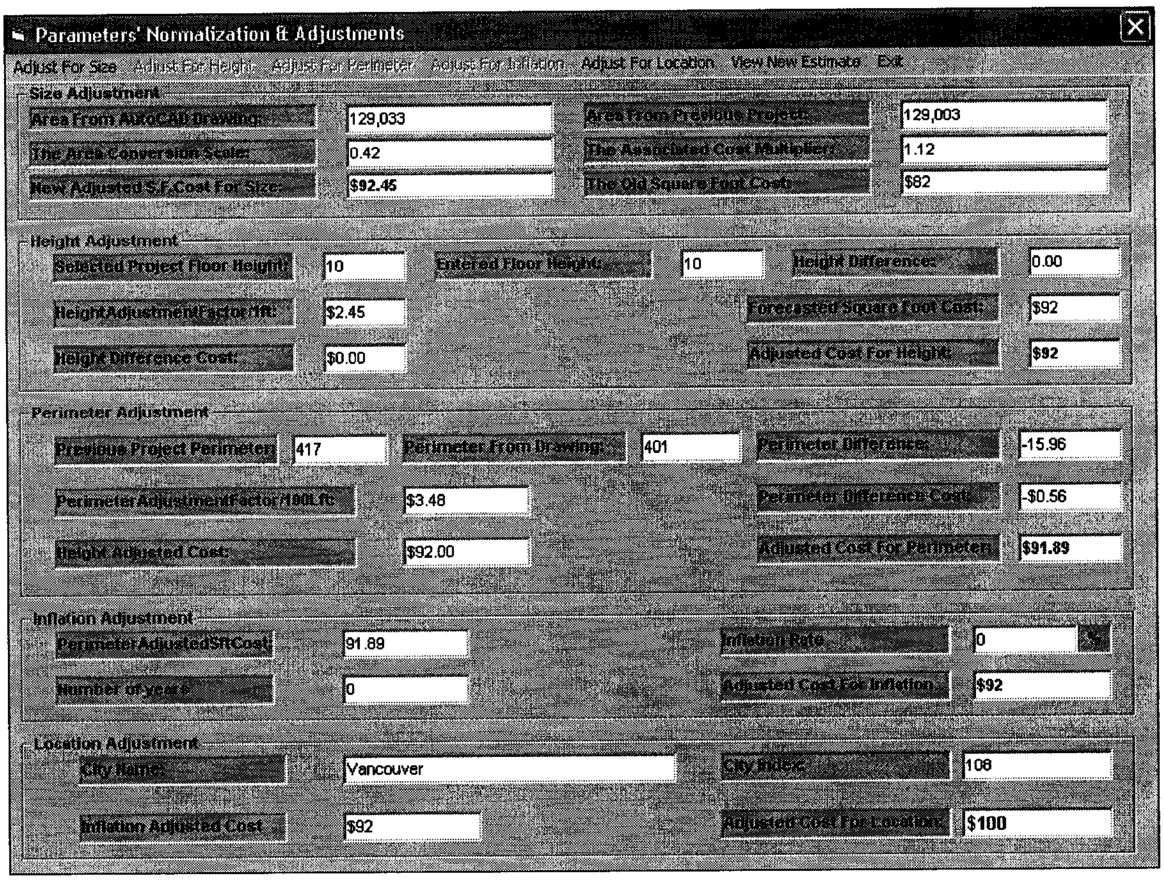

Figure 6.62 Automatic Adjustments Made by the System

Normally, the system forecasts the running costs of the selected project after sets of input are made, as mentioned previously in preceding paragraphs. Figures 6.65 and 6.66 show the form in which data have to be entered and the Life Cycle Costing Analysis output report generated by the system respectively.

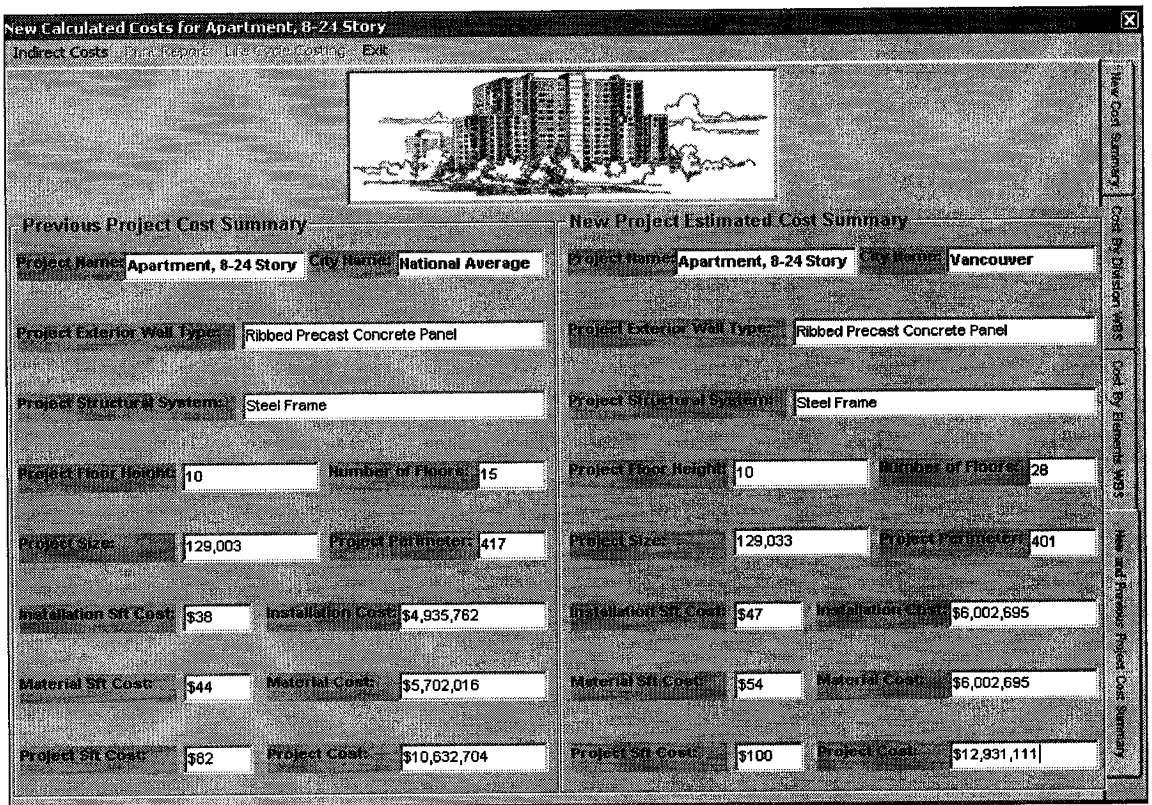

Figure 6.63 One of the New Cost Estimate Format Generated by the System

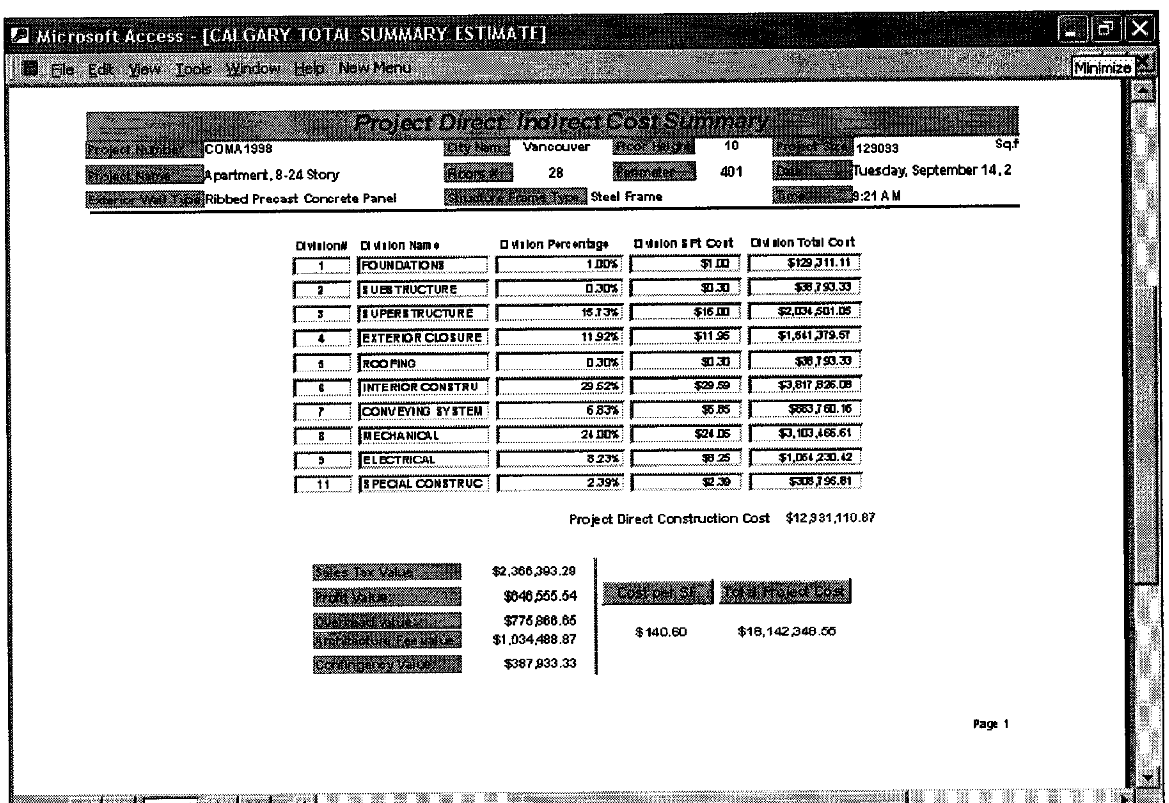

Figure 6.64 One of the Output Reports Provided by the System

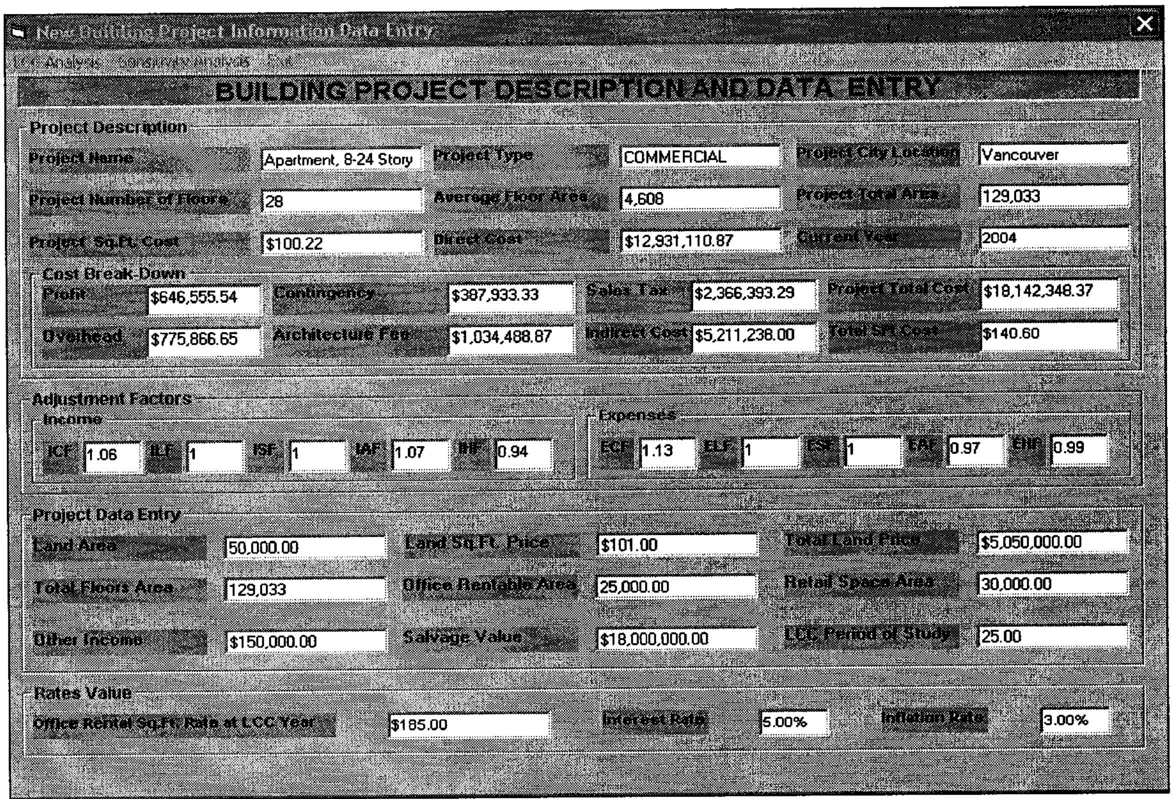

Figure 6.65 Life Cycle Costing Form to Input Required Data

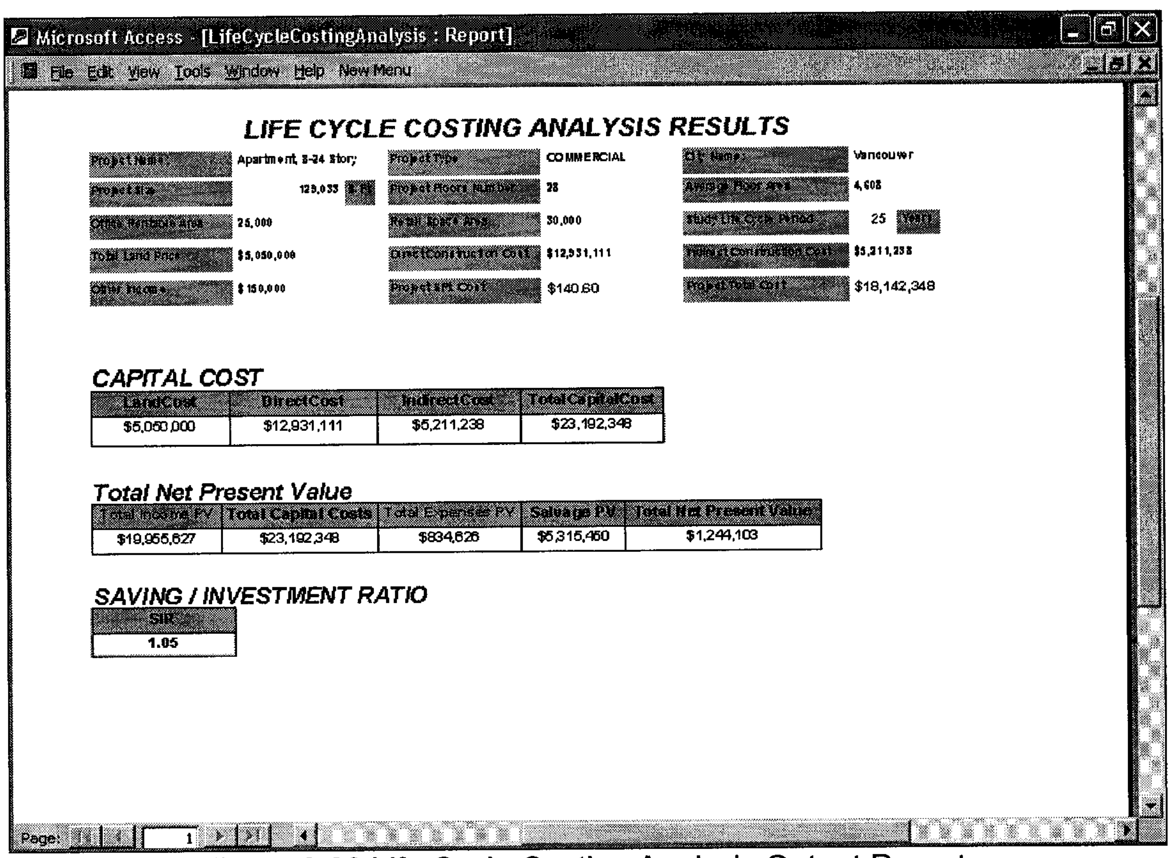

Figure 6.66 Life Cycle Costing Analysis Output Report

To apply the S.A. method, we input the range of errors and instantly the system executes all calculations and draws the graph as seen in Figures 6.67 and 6.68.

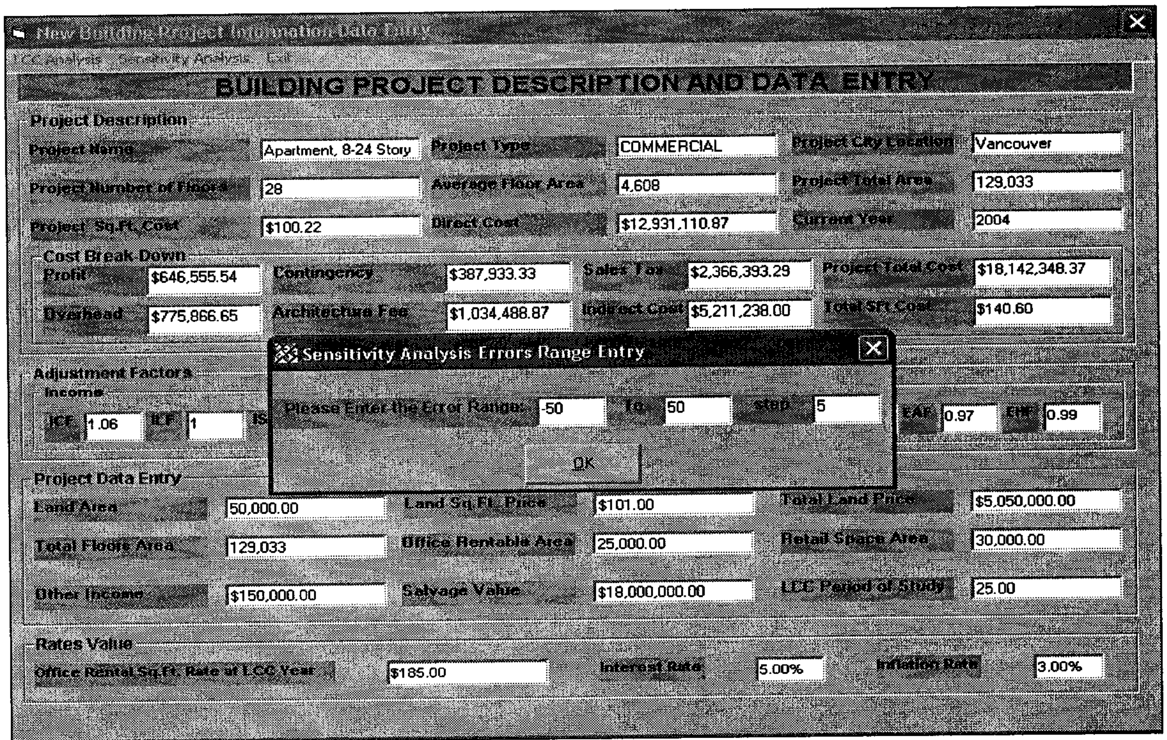

Figure 6.67 Entering the Range of Errors for the Sensitivity Analysis Method

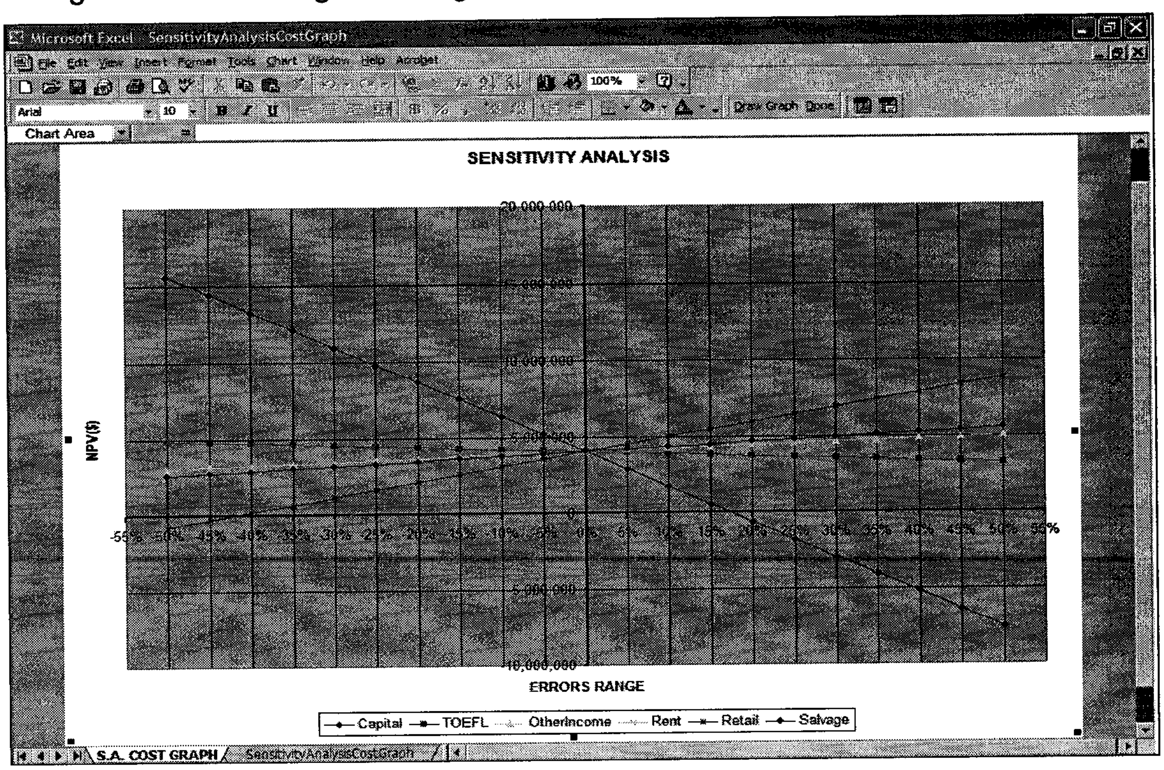

Figure 6.68 Sensitivity Analysis Graph

We could select the project type manually instead of running the DSS as explained in chapter Five paragraph 5.6.2.

6.5 Conclusion

The prototype system for conceptual cost estimate and life cycle costing for building projects is tested using an actual high-rise building project constructed by an owner-builder firm located in Vancouver in year 1996. The developed system incorporates three estimating tools that can be used separately according to user selection. These tools have been utilized to test the performance and capabilities of the system. The prototype provides an efficient prediction of the direct and indirect costs, besides foreseeing the future running costs of building projects. The results outcome showed a high level of accuracy compared to the actual values for the feasible stage of similar projects. Despite these outcomes are in imperial unit, it is possible to have them in the metric units too. Based on the prototype functions, the system encompasses interesting features:

- Uses a structurally modular format permitting future expansions and enhancements
- Executes required calculations and adjustments effectively
- Selects optimal project and 3D-CAD drawing through the relevance of the DSS dependably
- Foresees running costs of proposed building projects quickly
- Links AutoCAD and cost databases integrally
- Produces professional output reports

CHAPTER SEVEN

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

7.1 Summary

Preparing a project cost estimate is one of the major tasks that take place during the construction of any building project. This task becomes more complicated when owners require to know beforehand the predicted cost estimates of running and operating the building. Drawings, specifications, cost data, and experience are required to prepare reliable cost estimates. The application of Information technology (IT) to this process has proved to be useful in overcoming many difficulties during the construction of proposed projects.

This research presents a developed methodology for modeling the procedures of generating conceptual cost estimates and life cycle costing of building projects through the integration of 3D-CAD drawings, relational databases, linear regression and forecasting techniques. The methodology comprises parametric and preliminary cost estimate modules in both metric and imperial units, an AutoCAD module, a global visual basic module, a life cycle costing and sensitivity analysis module, and a linear regression and decision support system module. The system's databases and linear regression equations are based on R. S. Mean's National Average costs data published for the year 2000. Furthermore, the forecasting equations for life cycle costing are based on BOMA publications. The methodology possesses a number of fascinating features and advantages, which include the following:

- Producing parametric and preliminary cost estimates using Masterformat and Assembly work breakdown structures in both units
- Integrating 3D CAD drawings with relational databases to generate new parametric estimates
- Reading compulsory parameters instantly from 3D CAD drawings and writing them to external databases
- Automating necessary adjustments methods of the mentioned parameters
- Providing users with a wide range of selections so that their input is minimized
- Selecting best fitted projects and associated 3D CAD drawings through the relevance of decision support system
- Foreseeing the running costs of the proposed project within its anticipated service life
- Forecasting cost estimates of building projects based on either size or budget entry by using linear regression equations
- Supplying professional output reports in either tabulated or graphical format

Based on the prototype performance, it is obvious that the system has advantages that lie in the integration of many processes that a construction project passes through, besides its successful functionality and accurate outcomes. The measures applied within the system modules revealed realistic developments that group the cases involved, besides producing satisfactory decisions on selecting adequate projects.

The developed system is intended to assist owners, Architects, and cost engineers in generating an understanding of the cost of constructing building projects and their anticipated running costs at the very earliest stages. Furthermore, the system paves the way for users to create different scenarios through the integration of 3D-CAD drawings in an attempt to come up with the best project that meets their technical requirements and within limited budget.
Time reduction, fast calculations' execution, easy drawing modification, efficient estimated and running costs prediction, effective project selection, and professional output reports generation are some of the system's descriptive advantages. Databases are structured in a format that allows editing, addition, and modification easily and efficiently.

7.2 Limitations of the Developed System

It must be emphasized that the developed system can only be used to prepare conceptual cost estimates for building projects that are 1) commercial, 2) industrial and 3) institutional, based on R. S. Means cost data. The contractor cannot utilize the proposed system to prepare cost estimates for bidding purposes. Listed below are the system's specific limitations:

- The system considers only the exterior wall and structural framing types for building projects depending on their type and category
- The developed prototype incorporates data for low-rise and high-rise building projects only
- The system's cost data included in the databases as well as for deriving the linear regression equations are limited to nine values of total floor areas depending on the project's type
- The derived linear regression equations are for low-rise and high-rise buildings depending on their exterior wall and framing type only
- The system predicts the cost of maintaining and operating commercial building projects for eight major Canadian cities only.
- The system considers the TOEFEL Rate and the Other Income values as constant within the project's anticipated life
- The system considers the interest and inflation rates as being constant over the whole study period
- The system does not consider the anticipated energy costs
- The decision support system looks for projects the construction costs of which are up to 70 million dollars only
- The system does not consider the urban planning and location aspects of the proposed projects
- The 3D-CAD drawings database includes drawings that have an area difference of 1,500ft^2 for high-rise and 300ft^2 for low-rise

7.3 Research Contribution

The contributions of this research reside in the following:

1. The development of a conceptual cost estimating model for building projects. The model incorporates sets of relational databases, which have their cost data routed on R. S. Means publication in an attempt to make it beneficial for the construction industry.
2. The development of Visual Basic internal modules in AutoCAD to automate the process of reading and writing pertained 3D-CAD drawing parameters to an external database, so that new estimates can be produced
3. The development of linear regression modules to forecast cost estimates based on any entered value for the area or the budget. Sets of linear regression equations are derived depending on the project type and envelope.
4. The development of a ruled-based decision support system, which can be used to select best-fitted building shapes and associated 3D-CAD drawings based on the user's budget in a flexible and easy manner.
5. The development of a life cycle costing module that predicts the running costs of commercial building projects within their anticipated service life, in addition to the application of sensitivity analysis method.

7.4 Recommendations for Future Research

Notwithstanding that this research presents a functional system as a unique tool for owners, architects and cost engineers to be utilized in preparing conceptual cost estimates in both units by integrating different applications, it is a platform that can potentially be enhanced by future work. This may include:

1. Integrating Industrial Foundation Classes (IFC's) in the development of a smart system that incorporates 3D-CAD drawings with databases to store architectural components and accordingly generating new cost estimates
2. Designing and implementing similar systems for life cycle costing of infrastructure rehabilitation considering assets management
3. Increasing the number of linear regression equations for additional work items in an attempt to increase the accuracy of the forecasted estimates
4. Developing a forecasting system to predict the running costs of any type of building project taking energy consumption into account
5. Enhancing the decision support system by adding more rules or by the application of different approaches and artificial intelligence to increase the capability of selecting optimal projects during feasibility stages and within the user's budget
6. Implementing the system on the World Wide Web via Virtual Reality Environment.

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APPENDIX (A)

LIFE CYCLE COSTING APPLICATION PROBLEMS

&

TERMINOLOGY

LCC APPLICATION'S PROBLEMS

Assaf and others (2002) classify five categories of problems of life cycle costing which includes Knowledge, Data, Procedure, Management, and Cost problems. Each problem is discussed as follow:

1) **Knowledge Problems**

These type of problems enclose the following components:

- ***Unfamiliarity with the Design-to-Cost Concept;*** which means that the building selection and design system will be based on the total cost of the building along its life cycle. In some instance, system alternatives are evaluated using such analysis but this is an exception rather a rule.
- ***Lack of Knowledge of the Concept;*** many clients are unaware of the technique of life cycle costing and how it could help them to make a better investment decision.
- ***An Unknown Relationship Exists Between Initial Cost and Future Cost;*** some decision makers concentrate on the initial cost of a product or building and are not concerned with future running cost. Pressures on management to improve short-term gains emphasize this thinking. In fact, in most cases initial cost is not the largest single cost it is under 50 percent of the total ownership cost of the project.
- ***Unavailability of Enough References;*** because of the shortage of technical papers published on the subject of life cycle costing, the

concept tends to not be well known to most decision-makers in the construction industry.

2) Data Problems

Life cycle costing is heavily dependent on data. The data used should be of previously executed projects' and should include all types of data, such as cost, performance, occupancy and general description information. In the collecting and analyzing of data, the designer will be faced with many problems, including the following:

- ***Unavailability of Capital Cost Data;*** this includes all data associated with development of a facility and includes data related to fees, site, and other construction costs.
- ***Unavailability of maintenance Data;*** this includes all data associated with maintenance of a facility in used and includes data for regular repairs, predictive maintenance, and annual maintenance contracts.
- ***Unavailability of Operation Data;*** this includes all data associated with operating a facility, such as fuel, salaries of operators, and energy costs.
- ***Unavailability of Discount or Interest Rate Data;*** the interest rate incorporates both time and value of money, whereas the discount rate will be extracted from inflation. Selection of the discount rate should reflect the level of return on alternative investment or on the cost of borrowing the money.

- ***Unavailability of Time Life Data;*** this includes all data associated with an item's life or expected time for replacement.
- ***Large Volume of Data Needed;*** the volume of data that must be filtered in life cycle costing to obtain information is enormous. The information derived from these data is used as input for making an equally large number of decisions.
- ***Unavailability of a Standard Method for Collecting and Recording Data;*** ordinary collection of data by a client is done for accounting purposes that could not be used in life cycle cost calculations. Performance data will be more beneficial to life cycle costing than accounting data. There is no effort that has been done to establish a methodology for collecting and analyzing data.
- ***Unavailability of a Database Management System;*** a Database management system is needed that will provide structuring facilities with a system that is capable of expressing the relationship between the data items used for life cycle costing.

3) Procedures Problems

These type of problems enclose the following components:

- ***Unreliability of Decision Taken;*** alternatives should be investigated in simple and functional comparison. Any design decision will have an effect on the whole life cycle. In order to have reliable decision, the previous experience of designers, should be examined to verify reliability.

- ***Lack of Integrity of Forecast;*** in order to have integrity of forecast, information should be expressed in the context of what could happen, what should happen, and what did happen.
- ***A majority of Life Cycle Costing Calculations Involve Uncertainty;*** the decision is said to be uncertain if it has several possible outcomes. Most of data in life cycle costing is uncertain because much of it relates to the future, which will be affected by inflation and other factors. Assumptions and forecasts are made about cost of energy, cleaning, maintenance, etc.
- ***Unavailability of Qualified Staff;*** the availability of qualified staff, including quantity surveyors who can cover all phases of life cycle costing including the selection, study, generating of alternatives, and design evaluation will help in providing good results. The quantity surveyors need to have a flexible approach to life cycle costing and provide the required services.
- ***Unavailability of Qualified Consultants;*** the availability of qualified consultants that have certified staffs can help in doing life cycle costing.

4) Management Problems

These type of problems include the following components:

- ***Unacceptance of the Concept;*** some decision makers do not accept the concept of life cycle costing and consider only initial cost in their selection of alternatives.

- ***Government Non-Enforcement;*** some agencies or firms will simply carry out a system as far as it is requested by the government and consider the design job as routine work that does not have any room for improvement or introduction of good techniques.
- ***Management (Client) Pressure to Meet Budget Limits;*** budget limitations on construction resources are out of the problems that can obstruct the application of life cycle costing to search for alternatives.
- ***Unclear Benefits of Life Cycle Costing to Management (Client);*** an unclear knowledge of services that life cycle costing could provide is one of the problems in application. Life Cycle Costing can provide many services – it can give support for maintenance and operating budget, it can be used for planning, etc.
- ***Improper Planning and Control of Management Tasks at Different Life Cycle Costing Stages;*** although the concept of life cycle costing is used by some industries, the cost goals are still not achieved because of a lack of proper planning and control of the management tasks at the different stages of the life cycle.

5) Cost Problem

These type of problems enclose the following components:

- ***Cost Paid for Designer to Conduct Life Cycle Costing;*** in order for life cycle costing to be conducted efficiently, the designer should be paid for his effort.
- ***Cost Paid for Collecting Data;*** data collection is not free. There is a cost to collect and analyze data that has to be considered in life cycle costing.
- ***Difficulties in Defining Cost Elements;*** it is not easy to identify all cost elements for each facility when conducting life cycle costing.

LIFE CYCLE COSTING TERMINOLOGY (© BOMA International 2002)

1. **Administrative Expenses**

   Expenses directly connected with administration of a building including: payroll, taxes and fringe benefits for directly employed administrative personnel; allotted administrative fee; management fees; professional fees (such as legal fees, accounting, data processing, engineering consulting and auditing); employee expenses and general expenses of running and maintaining the Office of Building Management (such as supplies, furniture, telephone, temporary help and postage).

2. **Building Hours**

   The number of operating hours per week including Saturdays and Sundays for the building when the HVAC is supplied. Total hours cannot exceed 168 hours.

3. **Cleaning Expenses**

Expenditures incurred from both daytime and nighttime cleaning of offices and common areas. Includes expense categories, such as payroll for in-house janitorial support, contract services for both routine and special cleaning (window washing, carpet cleaning), trash removal (net of recycling cost / income), supplies and miscellaneous cleaning expenses.

4. **Fixed Expenses**

Expenditures for total land and building real estate taxes, building insurance (fire, casualty, errors and omissions), personal property tax, and other annual, periodic taxes such as excise tax, gross sales tax, or leasing tax. The fixed expense category does not include any fixed expenses that are not operational-related, such as ground rent, which is treated as a financial expense and is not reported in the *Experience Exchange Report.*

5. **Gross Parking Income**

Gross profit generated from parking facilities. Reported on a dollar per building rentable square foot basis.

6. **Leasing Expenses**

Directly expensed and amortized/depreciated expenditures directly related to the leasing of space including payroll, taxes, and fringe' benefits for directly employed leasing personnel, leasing related travel and entertainment expenses, advertising, leasing commissions, legal and professional fees incurred during lease negotiations and alteration expenditures made to retain current tenants or secure new tenants. Also includes expenses incurred to buyout existing tenants and other costs associated with the execution of leases such as document preparation costs and cash advances for moving expenses.

7. **Miscellaneous Income**

   Non-rental income generated from vending machines, pay telephones, signage, late charges, interest, special events, health club, recycling, concierge, etc.

8. **Office Area Income**

   Income generated from leasing office space. Includes base rent and other income categories such as additional rent (pass-through and/or operating cost escalations), base rent escalators, lease cancellations, and rent abatements. Rent abatements, which are a contra-income account, should be interpreted as having negative values.

9. **Office Occupancy (%)**

   Total occupied office square footage of the sample divided by the total office square footage.

10. **Other Area Income**

    Income generated from leasing other space such as storage space, and antenna and express parcel space rental, etc. grossed-up to 100% occupancy.

11. **Parking Expenses**

    Parking Expenses: Expenses directly connected with administration and operation of a fee based parking facility. A facility operating on a net basis should only report the building owner's parking related expenses. Cost incurred by a "Free" parking facility should be recorded as part of the general maintenance cost under Repairs/Maint. and/or Roads/Grounds.

12. Parking Ratio (Square Feet)

This is a weighted average measured as the average number of parking stalls per 1,000 gross building square feet.

13. Rentable/Gross Square Feet

Ratio of the total rentable square footage of the sample to the total constructed area of the sample. The closer the ratio is to 1, the greater percentage of the properties' square footage is rentable space. This ratio is designed to give the average efficiency ratio of the buildings in the sample.

14. Rentable to Usable Area

The rentable/usable ratio is a positive number that is greater than or equal to one, resulting from dividing the rentable area in a building by the usable area. This ratio describes the amount of space that the occupant can expect to utilize, versus the amount that is leased.

15. Repairs and Maintenance Expenses (Repair/Maint.)

Expenditures for the general repairs and maintenance of a building including common areas and general upkeep. Includes both in-house payroll for operating engineers and maintenance personnel, and contracted services for elevator, HVAC, electrical, structural/roof, plumbing, fire and life safety expenses and other building maintenance and supplies.

16. Retail Area Income

Income generated from leasing retail space in office buildings grossed-up to 100% occupancy. Such income may include base rent, operating expense escalation/recovery, percentage rents, lease cancellations, rent abatements (contra-income account), merchant association dues income and tenant services income.

17. Retail Occupancy (%)

Total occupied retail square footage of the sample divided by the total retail square footage.

18. Roads/Grounds Expenses

Expenditures related to the exterior maintenance of a building (such as the landscaping, snow removal, parking lot repairs, site signage, site lighting, etc.). Includes payroll, taxes, and fringe benefits for directly employed roads/grounds personnel, expenses for individuals/firms contracted to perform specified duties and supplies (fertilizer, ice melt chemicals). Parking area maintenance expenses are included in this category only for buildings that do not charge a parking fee.

19. Security Expenses

Expenditures related to the security of tenants and the building including payroll and fringe benefits for security personnel as well as expenses for individuals/firms contracted to perform specified duties and provide supplies. Also includes expenses of maintenance of security systems and ordinary supplies necessary to operate a security program such as security access cards, security system components, batteries and control forms as well as any other miscellaneous security expenses such as security personnel uniforms.

20. Square Feet per Maintenance Staff

The average number of building square feet per dedicated on-site, full-time building maintenance and engineering employee. Contract maintenance staff is included in this calculation if they work full-time at the building site.

21. Square Feet per Office Tenant

The average number of square feet occupied by individual office leaseholders, including owners, in a building. This number is calculated by dividing the total amount of occupied square feet in the sample by the total number of tenants.

22. Square Feet per Office Worker

The average amount of square feet occupied by each individual office worker in a building. The average is calculated by dividing the total amount of occupied office square feet in the sample by the total number of office workers. The average square feet per office worker reflects the average square footage allotted to an office worker regardless of position, and includes workers at every level.

23. Square Feet per Retail Tenant

The average amount of square feet occupied by individual retail leaseholders. This number is calculated by dividing the total amount of occupied retail square feet in the sample by the total number of retail tenants.

24. Telecom Income/Expenses

Income that is derived from Telecommunications within a building. There are two sources of income highlighted in the EER-"Wire Access" includes total income derived from telecommunications providers for wire access to the building and "Rooftop Access" includes total income telecommunications providers for rooftop access to the building. These two income items are then added to arrive at a "Total Telecom" income figure. This total income is still/also reported as "Other Space Rent".

"Telecom Expenses" include all expenses incurred by the owner/manager and are associated with the above-noted telecom income. If any telecom expenses have been amortized or depreciated, only those portions incurred in 2001 have been reported.

25. Tenant Service Income

Income that is derived from services rendered to/for the tenants outside of the lease documents. This category would include such things as after-hour HVAC or electricity, cleaning, repair/maintenance, security and so forth.

26. Total BTU's

British Thermal Units (Btu) is an indication of the total energy consumption for an entire building. The following conversion factors were utilized to determine Btu's

1) Annual electricity (kWh) x 3413;

2) Annual natural gas (therms) x 100,000 or annual natural gas (ccf) x 1030;

3) Annual propane (gal) x 91,333;

4) Purchased steam (1,000 lbs.) x 1,000,000;

5) Purchased chill water (1,000 tons-hrs) x 3,413,000;

6) Fuel oil (gal) x 91,333.

27. Total Income

Total of rental income, tenant service income, miscellaneous (non-rental) income, and gross parking income.

28. Total Operating and Fixed Expenses

Total of all expenditures including cleaning, repairs/maintenance, utilities, roads/ grounds, security, administrative and fixed expenses.

29. Total Operating Expenses

Total of all cleaning, repairs/maintenance, utilities, roads/grounds, security, and administrative expenses.

30. Total Rent

Total of rental income produced from office, retail, and other space, if applicable.

31. Utility Expenses

Expenditures for all utilities including electricity, gas, fuel oil, purchased steam, purchased chilled water, coal, and water/ sewer. Both directly metered and sub-metered utilities are included, even if tenants pay their utility bills directly.

32. Year-End Rent ($)

The average base rent of the last space rented during the calendar year 2001. The year-end base rent is calculated by first multiplying the year-end dollar per square foot base rent by the square footage of office space of each building. The dollar amounts for each building are totaled and then divided by the total square footage of office space. Average dollar rate year-end rent is not the equivalent of the current market rental rate since it averages asking rents that could have occurred any time during the year. It is, however, a strong indicator of the actual, contracted rate at which space was leased.

APPENDIX (B)

LIFE CYCLE COSTING ANALYSIS

Table B-1 Office Rental ($/SF)

Year	BOMA – 5 YEARS (50 Identical Buildings) 1989 (X_1)	1990 (X_2)	1991 (X_3)	1992 (X_4)	1993 (X_5)	1994 (X_6)	1995 (X_7)	1996 (X_8)	BOMA YEARLY REPORT (200 BLDGs) (X_9)
1984	16.65								
1985	16.84	16.73							
1986	17.35	17.28	17.92						
1987	18.73	18.41	18.91	19.03					
1988	19.96	19.47	20.16	20.64	20.98				18.63
1989		20.98	21.57	22.92	23.40				21.09
1990			20.63	21.17	20.96				20.62
1991				21.05	22.33			23.15	21.75
1992					26.72			26.80	23.63
1993								24.15	22.57
1994								22.16	22.28
1995								20.06	21.34
1996									19.79
1997									18.80

Table B-2 Office Retail ($/SF)

Year	BOMA – 5 YEARS (50 Identical Buildings) 1989 (X_1)	1990 (X_2)	1991 (X_3)	1992 (X_4)	1993 (X_5)	1994 (X_6)	1995 (X_7)	1996 (X_8)	BOMA YEARLY REPORT (200 BLDGs) (X_9)
1984	18.25								
1985	19.26	17.28							
1986	19.27	17.86	17.62						
1987	20.96	19.83	19.51	18.76					
1988	21.72	21.56	21.83	22.19	25.68				22.31
1989		22.92	23.48	23.96	26.57				24.67
1990			21.53	21.56	24.98				21.78
1991				23.89	27.34			27.97	23.70
1992					27.63			28.56	25.80
1993								26.72	23.71
1994								26.72	23.47
1995								27.12	22.63
1996									22.57
1997									15.91

Table B-3 TOEFEL ($/SF)

YEAR	BOMA – YEARLY REPORT (200 Buildings)
1988	9.27
1989	10.09
1990	11.44
1991	11.78
1992	12.23
1993	12.67
1994	12.08
1995	12.06
1996	11.90
1997	11.69

Table B-4 CPI (All Items/Rent) and Retail $ Value (Statistics Canada)

Year	CPI (All Items)			CPI (Rent)		Retail Per year ($x1000)		
	Canada	Quebec	Montreal	Canada	Quebec	Canada	Quebec	Montreal
1981	58.9	58.0	57.6	59.6	57.0			
1982	65.3	64.7	64.2	65.0	62.5			
1983	69.1	68.3	67.8	69.9	69.1	116,566,937	28,858,868	N/A
1984	72.1	71.1	70.6	73.4	73.5	127,413,320	32,446,066	N/A
1985	75.0	74.2	73.7	76.5	77.1	142,211,755	35,567,158	N/A
1986	78.1	77.7	77.3	79.6	80.8	153,785,657	38,703,480	N/A
1987	81.5	81.1	80.8	82.6	84.2	168,893,551	43,456,327	N/A
1988	84.8	84.1	83.9	85.9	87.7	181,652,071	46,583,391	N/A
1989	89.0	87.7	87.6	90.4	92.0	189,301,628	47,191,950	N/A
1990	93.3	91.5	91.4	94.1	95.0	192,558,231	47,578,154	N/A
1991	98.5	98.2	98.1	97.3	97.7	181,614,439	44,864,143	20,640,978
1992	100.0	100.0	100.0	100.0	100.0	185,169,503	44,837,111	20,290,437
1993	101.8	101.4	101.4	102.2	101.8	194,324,749	46,889,958	21,187,684
1994	102.0	100.0	99.9	103.9	103.2	207,840,624	49,598,020	22,315,966
1995	104.2	101.8	101.7	105.5	104.4	213,773,669	49,291,775	21,891,045
1996	105.9	103.4	103.4	106.9	105.3	220,869,830	52,086,048	23,158,171
1997	107.6	104.9	104.8	108.1	106.0	237,836,642	55,866,328	25,474,326
1998	108.6	106.4	106.5	109.2	106.5	246,674,830	57,162,261	26,769,126
1999	110.5	108.0	108.2	110.2	107.1	260,779,457	60,778,033	28,099,118
2000	113.5	110.6	110.7	111.4	107.7	277,033,166	63,480,947	29,365,694
2001	116.4	113.2	113.4	113.2	108.7	289,129,995	66,036,352	30,358,779
2002	119.0	115.5	115.7	115.4	109.9	306,365,631	70,069,935	32,169,301

For CPI, 1992=100
There is no CPI (rent) for Montreal
N/A: Not Available

B. - 1) AVERAGE-BASED DATA SET FOR RENT AND RETAIL

1). Based on the overall average by averaging up all the horizontal values corresponding to each year separately using the following expression:

$$Y = \frac{\left(\sum_{i=1}^{w} X_i\right)}{w}$$

Where: (w) is the number of periods

(Y) is the overall average for the year in question

(x_i) is the value for year (i)

The followings table and graph illustrate this matter

Table B-5 Rental ($/SF) Based on Overall Average Values

Year	BOMA – 5 YEARS (50 Identical Buildings)								BOMA YEARLY REPORT (200 buildings) (X_9)	OVERALL AVERAGE (Y)
	1989 (X_1)	1990 (X_2)	1991 (X_3)	1992 (X_4)	1993 (X_5)	1994 (X_6)	1995 (X_7)	1996 (X_8)		
1984	16.65									**16.65**
1985	16.84	16.73								**16.79**
1986	17.35	17.28	17.92							**17.52**
1987	18.73	18.41	18.91	19.03						**18.77**
1988	19.96	19.47	20.16	20.64	20.98				18.63	**19.97**
1989		20.98	21.57	22.92	23.40				21.09	**21.99**
1990			20.63	21.17	20.96				20.62	**20.85**
1991				21.05	22.33			23.15	21.75	**22.07**
1992					26.72			26.80	23.63	**25.72**
1993								24.15	22.57	**23.36**
1994								22.16	22.28	**22.22**
1995								20.06	21.34	**20.7**
1996									19.79	**19.79**
1997									18.80	**18.80**

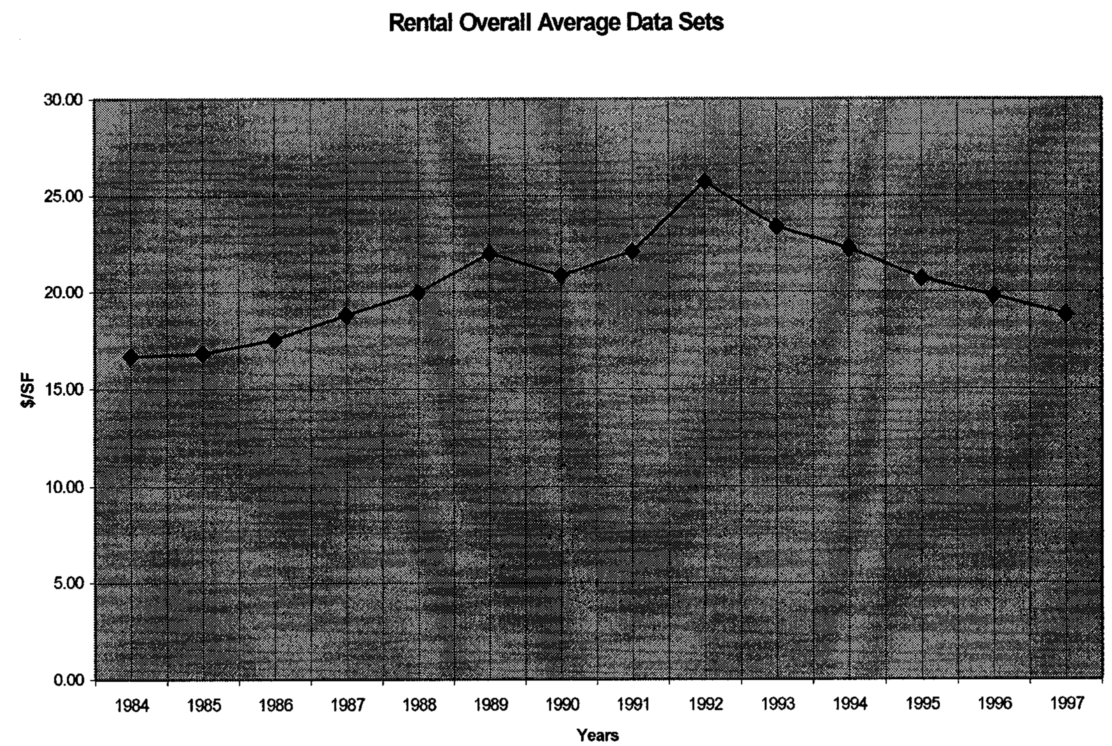

Figure B.1 Rental Overall Average

2). Based on a weighted average supported by the number of buildings that originated the data (5 Years Report for 50 identical buildings versus yearly report for 200 buildings), where the number of buildings is 250 (50+200) and the weights are (50/250=1/5) and (200/250=4/5) respectively using the following expression:

$$Y = \left(\left(\frac{\sum_{i=1}^{w} x_i}{w} \right)_{(50\,buildings)} \right) * \left(\frac{1}{5} \right) + \left(\left(z_i \right)_{(200\,buildings)} \right) * \left(\frac{4}{5} \right)$$

Where: (w) is the number of periods for the 50 buildings values

(Y) is the weighted average for the year in question

(x_i) is the value of year (i) for the 50 buildings values

(z_i) is the value of year (i) for the 200 buildings

Table B-6 Rental ($/SF) Based on Weighted Average Values

Year	BOMA – 5 YEARS (50 Identical Buildings)								AVERAGE	BOMA YEARLY REPORT (200 buildings) (Z_i)	WEIGHTED AVERAGE (Y)
	1989 (X_1)	1990 (X_2)	1991 (X_3)	1992 (X_4)	1993 (X_5)	1994 (X_6)	1995 (X_7)	1996 (X_8)			
1984	16.65								16.65		**16.65**
1985	16.84	16.73							16.79		**16.79**
1986	17.35	17.28	17.92						17.52		**17.52**
1987	18.73	18.41	18.91	19.03					18.77		**18.77**
1988	19.96	19.47	20.16	20.64	20.98				20.24	18.63	**18.95**
1989		20.98	21.57	22.92	23.40				22.22	21.09	**21.32**
1990			20.63	21.17	20.96				20.92	20.62	**20.68**
1991				21.05	22.33			23.15	22.18	21.75	**21.84**
1992					26.72			26.80	26.76	23.63	**24.26**
1993								24.15	24.15	22.57	**22.89**
1994								22.16	22.16	22.28	**22.26**
1995								20.06	20.06	21.34	**21.08**
1996										19.79	**19.79**
1997										18.80	**18.80**

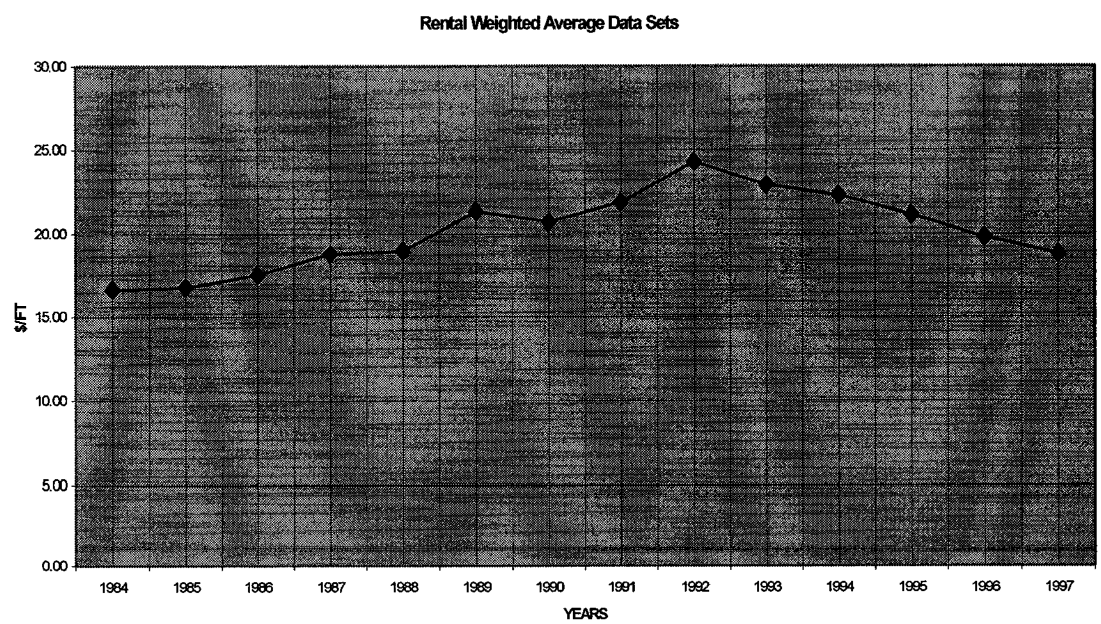

Figure B.2 Rental Weighted Average

Same procedures are followed concerning the retail data sets; the resulting values and graphs are shown in Tables B-7, B-8 and Figures B-3, B-4.

Table B-7 Retail ($/SF) Based on Overall Average Values

Year	BOMA – 5 YEARS (50 Identical Buildings)								BOMA YEARLY REPORT (200 buildings) (X_9)	OVERALL AVERAGE (Y)
	1989 (X_1)	1990 (X_2)	1991 (X_3)	1992 (X_4)	1993 (X_5)	1994 (X_6)	1995 (X_7)	1996 (X_8)		
1984	18.25									18.25
1985	19.26	17.28								18.27
1986	19.27	17.86	17.62							18.25
1987	20.96	19.83	19.51	18.76						19.77
1988	21.72	21.56	21.83	22.19	5.68				22.31	19.22
1989		22.92	23.48	23.96	26.57				24.67	24.32
1990			21.53	21.56	24.98				21.78	22.46
1991				23.89	27.34			27.97	23.70	25.73
1992					27.63			28.56	25.80	27.33
1993								26.72	23.71	25.22
1994								26.72	23.47	25.10
1995								27.12	22.63	24.88
1996									22.57	22.57
1997									15.91	15.91

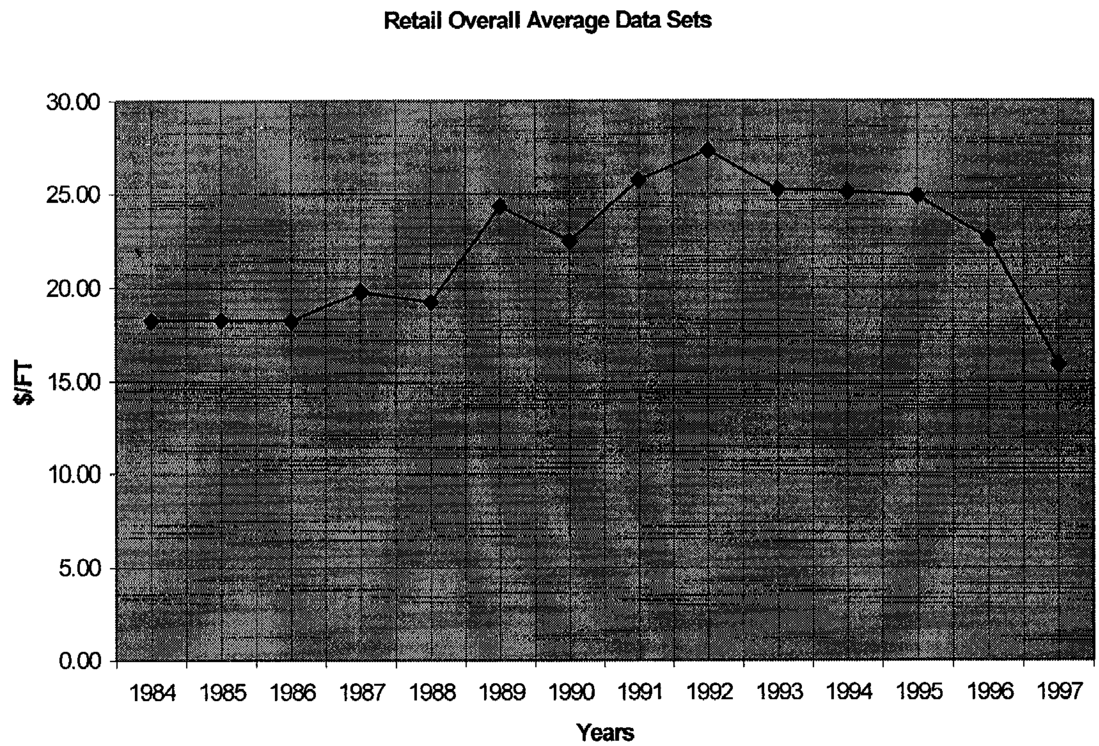

Figure B.3 Retailed Overall Average

Table B-8 Retail ($/SF) Based on Weighted Average Values

Year	BOMA – 5 YEARS (50 Identical Buildings)								AVERAGE	BOMA YEARLY REPORT (200 buildings) (Z_i)	WEIGHTED AVERAGE (Y)
	1989 (X_1)	1990 (X_2)	1991 (X_3)	1992 (X_4)	1993 (X_5)	1994 (X_6)	1995 (X_7)	1996 (X_8)			
1984	18.25								18.25		**18.25**
1985	19.26	17.28							18.27		**18.27**
1986	19.27	17.86	17.62						18.25		**18.25**
1987	20.96	19.83	19.51	18.76					19.77		**19.77**
1988	21.72	21.56	21.83	22.19	5.68				18.60	22.31	**21.57**
1989		22.92	23.48	23.96	26.57				24.23	24.67	**24.58**
1990			21.53	21.56	24.98				22.69	21.78	**21.96**
1991				23.89	27.34			27.97	26.40	23.70	**24.24**
1992					27.63			28.56	28.10	25.80	**26.26**
1993								26.72	26.72	23.71	**24.31**
1994								26.72	26.72	23.47	**24.12**
1995								27.12	27.12	22.63	**23.53**
1996										22.57	**22.57**
1997										15.91	**15.91**

Retail Weighted Average Data Sets

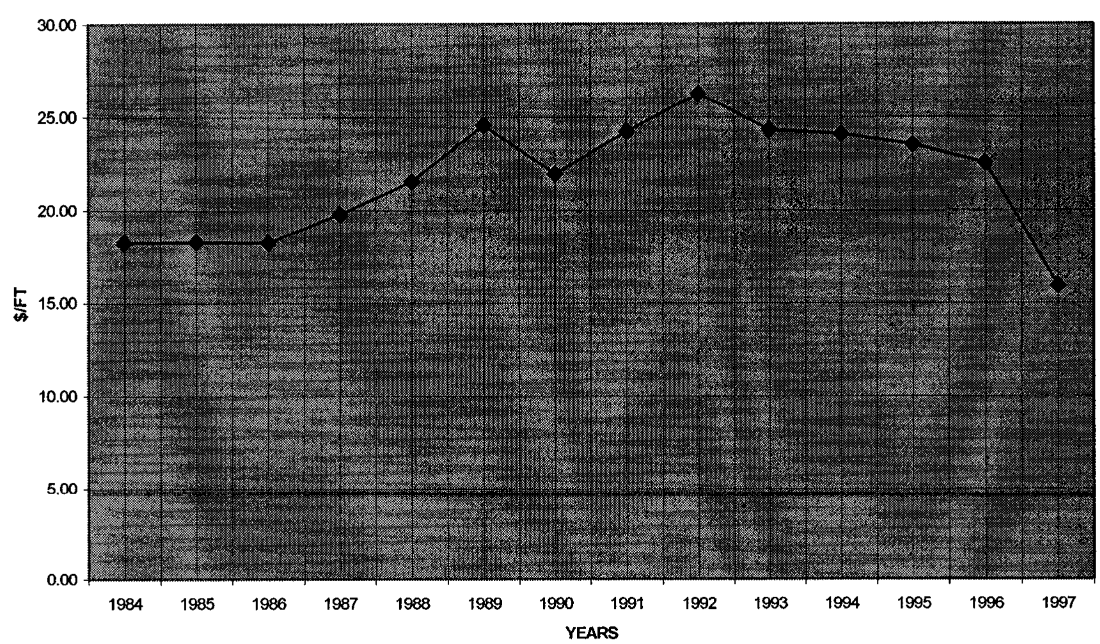

Figure B.4 Retailed Weighted Average

B.- 2) Forecasting Methods For Rent

1- Moving Average

a) Incremental Number of Years Average ($/SF): in this method the basis years are: 2, 3, 4,and 5 respectively, where the following expression is used:

$$Y = \left(\frac{\sum_{i=1}^{n} X_i}{n} \right)$$

Where, (n) is the number of years, (Y) is the year for which the value is calculated, and (X_i) is the value at base year (i), as illustrated in Table B-9.

Table B-9 Moving Average – Incremental Number of Years Average

YEAR	ACTUAL ($\$/ft^2$) ($X_i$)	YEARS BASIS 2 Years n=2	3 Years n=3	4 Years n=4	5 Years n=5
1984	16.65				
1985	16.79				
1986	17.52	16.72			
1987	18.77	17.15	16.98		
1988	18.95	18.14	17.69	17.43	
1989	21.32	18.86	18.41	18.01	17.73
1990	20.68	20.13	19.68	19.14	18.67
1991	21.84	21.00	20.32	19.93	19.45
1992	24.26	21.26	21.28	20.70	20.31
1993	22.89	23.05	22.26	22.02	21.41
1994	22.26	23.57	22.99	22.41	22.19
1995	21.08	22.57	23.13	22.81	22.38
1996	19.79	21.67	22.08	22.62	22.46
1997	18.80	20.44	21.04	21.50	22.05
Coefficient of Correlation (R^2) with the Actual		**0.71**	**0.50**	**0.21**	**-0.20**

b) 2 Years Moving Average ($/SF): in this method the recent year weight (*w*) is: 2/3, 3/4, 4/5, 5/6, and 9/10 respectively, where the following expression is used:

$$Y = X_i - W_i * (X_i - X_{(i+1)})$$

Table B-10 (2)-Years Moving Average – Weighted in Favor of the Recent Year ($/SF)

YEAR	ACTUAL ($/ft²) ($X_i$)	RECENT YEAR WEIGHT				
		$W_i = \frac{2}{3}$	$W_i = \frac{3}{4}$	$W_i = \frac{4}{5}$	$W_i = \frac{5}{6}$	$W_i = \frac{9}{10}$
1984	16.65					
1985	16.79					
1986	17.52	16.74	16.75	16.76	16.76	16.77
1987	18.77	17.27	17.33	17.37	17.39	17.44
1988	18.95	18.35	18.46	18.52	18.56	18.64
1989	21.32	18.89	18.91	18.92	18.92	18.93
1990	20.68	20.53	20.72	20.84	20.92	21.08
1991	21.84	20.89	20.84	20.81	20.79	20.74
1992	24.26	21.45	21.55	21.60	21.64	21.72
1993	22.89	23.45	23.65	23.77	23.85	24.01
1994	22.26	23.34	23.23	23.16	23.11	23.02
1995	21.08	22.47	22.41	22.38	22.36	22.32
1996	19.79	21.47	21.38	21.32	21.28	21.20
1997	18.80	20.22	20.11	20.05	20.01	19.92
Coefficient of Correlation (R^2) with the Actual		**0.74**	**0.76**	**0.77**	**0.77**	**<u>0.78</u>**

c) 3 Years Moving Average ($/SF): in this method the recent year weight (*w*) is: 2/4, 3/5, 4/6, 5/7, 6/8, 7/9, 9/11, 11/13, and 12/14 respectively, where the following expression is used:

$$Y = \left(\frac{1\text{-}Wi}{2}\right) * (X_i + X_{(i+1)}) + W_i * X_{(i+2)}$$

Table B-11 (3)-Years Moving Average – Weighted in Favor of the Recent Year ($/SF)

YEAR	ACTUAL ($/ft²) ($X_i$)	RECENT YEAR WEIGHT								
		$W_i = \frac{2}{4}$	$W_i = \frac{3}{5}$	$W_i = \frac{4}{6}$	$W_i = \frac{5}{7}$	$W_i = \frac{6}{8}$	$W_i = \frac{7}{9}$	$W_i = \frac{9}{11}$	$W_i = \frac{11}{13}$	$W_i = \frac{12}{14}$
1984	16.65									
1985	16.79									
1986	17.52									
1987	18.77	17.12	17.20	17.25	17.29	17.32	17.34	17.37	17.39	17.40
1988	18.95	17.96	18.12	18.23	18.31	18.37	18.41	18.48	18.52	18.54
1989	21.32	18.55	18.63	18.68	18.72	18.75	18.77	18.81	18.83	18.84
1990	20.68	20.09	20.33	20.50	20.61	20.70	20.77	20.87	20.94	20.96
1991	21.84	20.41	20.46	20.50	20.52	20.54	20.56	20.58	20.60	20.60
1992	24.26	21.42	21.50	21.56	21.60	21.63	21.65	21.68	21.71	21.72
1993	22.89	22.76	23.06	23.26	23.40	23.51	23.59	23.71	23.79	23.83
1994	22.26	22.97	22.95	22.94	22.93	22.93	22.92	22.92	22.91	22.91
1995	21.08	22.91	22.78	22.69	22.63	22.58	22.55	22.50	22.46	22.44
1996	19.79	21.83	21.68	21.58	21.51	21.46	21.41	21.35	21.31	21.30
1997	18.80	20.73	20.54	20.42	20.33	20.26	20.21	20.13	20.08	20.06
Coefficient of Correlation (R^2) with the Actual		0.57	0.60	0.62	0.64	0.65	0.66	0.67	0.68	0.68

Table B-12 Actual vs. Forecast Values (2 Years Moving Weighted Average Favoring the Last Year by 9/10)

Year	ACTUAL ($/ft²) ($X_i$)	FORECAST	
1984	16.65		
1985	16.79		
1986	17.52	16.77	
1987	18.77	17.44	
1988	18.95	18.64	
1989	21.32	18.93	
1990	20.68	21.08	
1991	21.84	20.74	
1992	24.26	21.72	
1993	22.89	24.01	
1994	22.26	23.02	
1995	21.08	22.32	
1996	19.79	21.20	
1997	18.80	19.92	
1998		18.90	=18.80*9/10+19.79*1/10
1999		18.98	=18.90*8/10+18.80*1/10+19.79*1/10
2000		19.03	=18.98*7/10+18.90*8/10+18.80*1/10+19.79*1/10
2001		19.07	=19.03*6/10+18.98*1/10+18.90*8/10+18.80*1/10+19.79*1/10
2002		19.08	=19.07*5/10+19.03*1/10+18.98*1/10+18.90*8/10+18.80*1/10+19.79*1/10

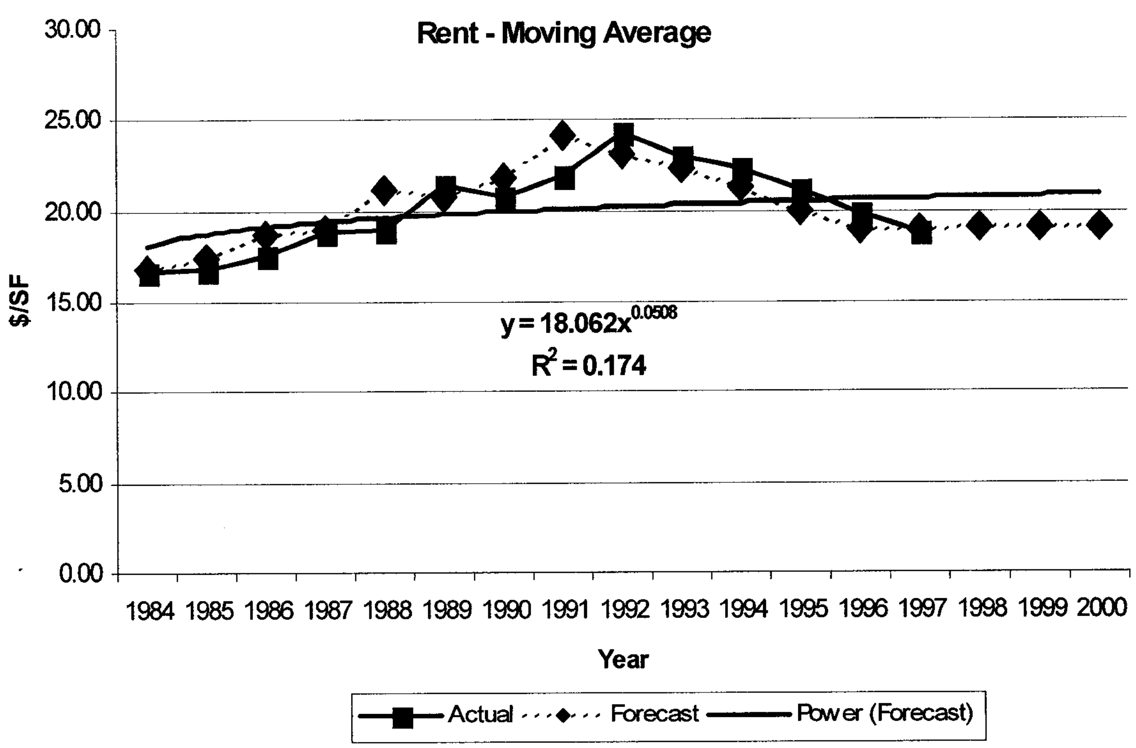

Figure B.5 Actual vs. Forecast with the Best Trend Line

Although the forecasted data correlates with the actual one and their plot give approximately the same shape indicating similar fluctuation, as shown in Table

B-12 and Figure B.5, the best trend line obtained has a low value of R^2 (0.174) and the forecast data for the years 1998 to 2002 have more or less similar values due to the nature of the calculations. Thus, the use of averages for this operation is not expected to provide reliable data.

2- Smoothed Forecasting

1) for $\alpha = 0.05$

Table B-13 Smoothed Forecast for $\alpha = 0.05$

Year	Actual Value ($/ft²) (2)	Last Year Value ($/ft²) (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.05	0.83	0.95	16.72	15.88	16.71
1986	17.52	16.79	0.05	0.84	0.95	16.71	15.88	16.72
1987	18.77	17.52	0.05	0.88	0.95	16.72	15.88	16.76
1988	18.95	18.77	0.05	0.94	0.95	16.76	15.92	16.86
1989	21.32	18.95	0.05	0.95	0.95	16.86	16.02	16.96
1990	20.68	21.32	0.05	1.07	0.95	16.96	16.11	17.18
1991	21.84	20.68	0.05	1.03	0.95	17.18	16.32	17.36
1992	24.26	21.84	0.05	1.09	0.95	17.36	16.49	17.58
1993	22.89	24.26	0.05	1.21	0.95	17.58	16.70	17.91
1994	22.26	22.89	0.05	1.14	0.95	17.91	17.02	18.16
1995	21.08	22.26	0.05	1.11	0.95	18.16	17.25	18.37
1996	19.79	21.08	0.05	1.05	0.95	18.37	17.45	18.50
1997	18.80	19.79	0.05	0.99	0.95	18.50	17.58	18.57
1998		18.80	0.05	0.94	0.95	18.57	17.64	18.58

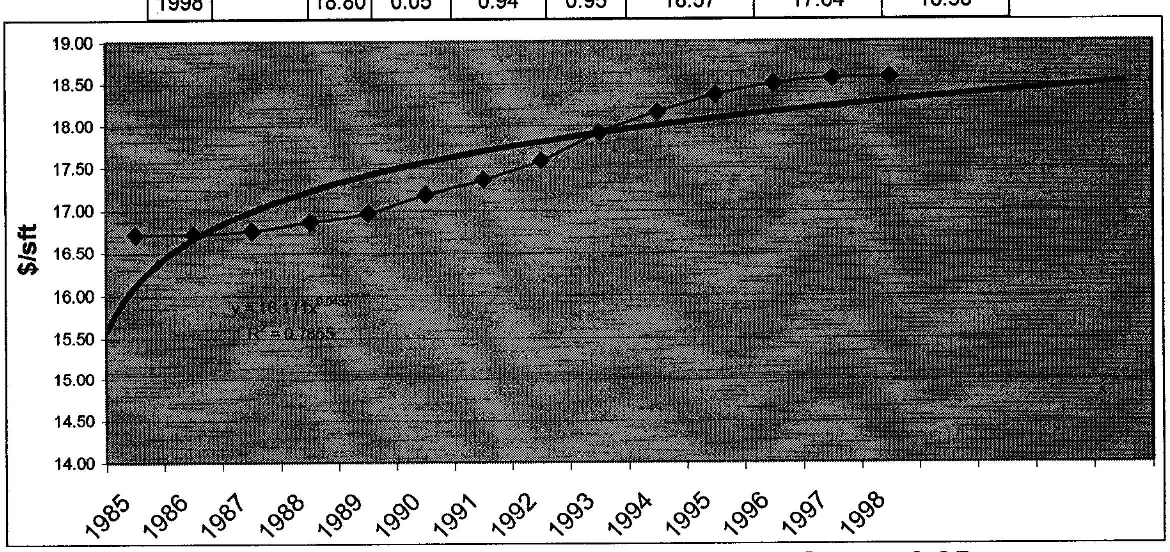

Figure B.6 Smoothed Rental Trend Line for $\alpha = 0.05$

2) for $\alpha = 0.1$

Table B-14 Smoothed Forecast for α = 0.1

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.1	1.67	0.90	16.72	15.05	16.71
1986	17.52	16.79	0.1	1.68	0.90	16.71	15.04	16.72
1987	18.77	17.52	0.1	1.75	0.90	16.72	15.05	16.80
1988	18.95	18.77	0.1	1.88	0.90	16.80	15.12	17.00
1989	21.32	18.95	0.1	1.90	0.90	17.00	15.30	17.19
1990	20.68	21.32	0.1	2.13	0.90	17.19	15.47	17.60
1991	21.84	20.68	0.1	2.07	0.90	17.60	15.84	17.91
1992	24.26	21.84	0.1	2.18	0.90	17.91	16.12	18.30
1993	22.89	24.26	0.1	2.43	0.90	18.30	16.47	18.90
1994	22.26	22.89	0.1	2.29	0.90	18.90	17.01	19.30
1995	21.08	22.26	0.1	2.23	0.90	19.30	17.37	19.59
1996	19.79	21.08	0.1	2.11	0.90	19.59	17.63	19.74
1997	18.80	19.79	0.1	1.98	0.90	19.74	17.77	19.75
1998		18.80	0.1	1.88	0.90	19.75	17.77	19.65

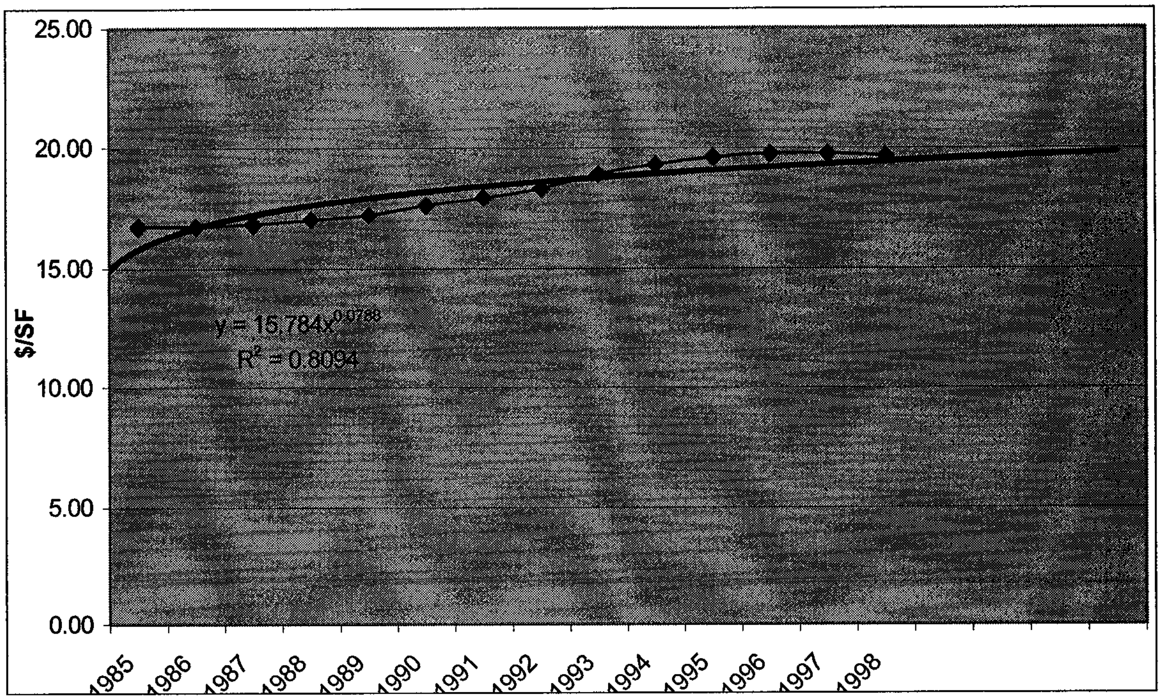

Figure B.7 Smoothed Rental Trend Line for α = 0.1

3) for α = 0.15

Table B-15 Smoothed Forecast for α = 0.15

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.15	2.50	0.85	16.72	14.21	16.71
1986	17.52	16.79	0.15	2.52	0.85	16.71	14.20	16.72
1987	18.77	17.52	0.15	2.63	0.85	16.72	14.21	16.84
1988	18.95	18.77	0.15	2.82	0.85	16.84	14.31	17.13
1989	21.32	18.95	0.15	2.84	0.85	17.13	14.56	17.40
1990	20.68	21.32	0.15	3.20	0.85	17.40	14.79	17.99
1991	21.84	20.68	0.15	3.10	0.85	17.99	15.29	18.39
1992	24.26	21.84	0.15	3.28	0.85	18.39	15.63	18.91
1993	22.89	24.26	0.15	3.64	0.85	18.91	16.07	19.71
1994	22.26	22.89	0.15	3.43	0.85	19.71	16.75	20.19
1995	21.08	22.26	0.15	3.34	0.85	20.19	17.16	20.50
1996	19.79	21.08	0.15	3.16	0.85	20.50	17.42	20.59
1997	18.80	19.79	0.15	2.97	0.85	20.59	17.50	20.47
1998		18.80	0.15	2.82	0.85	20.47	17.40	20.22

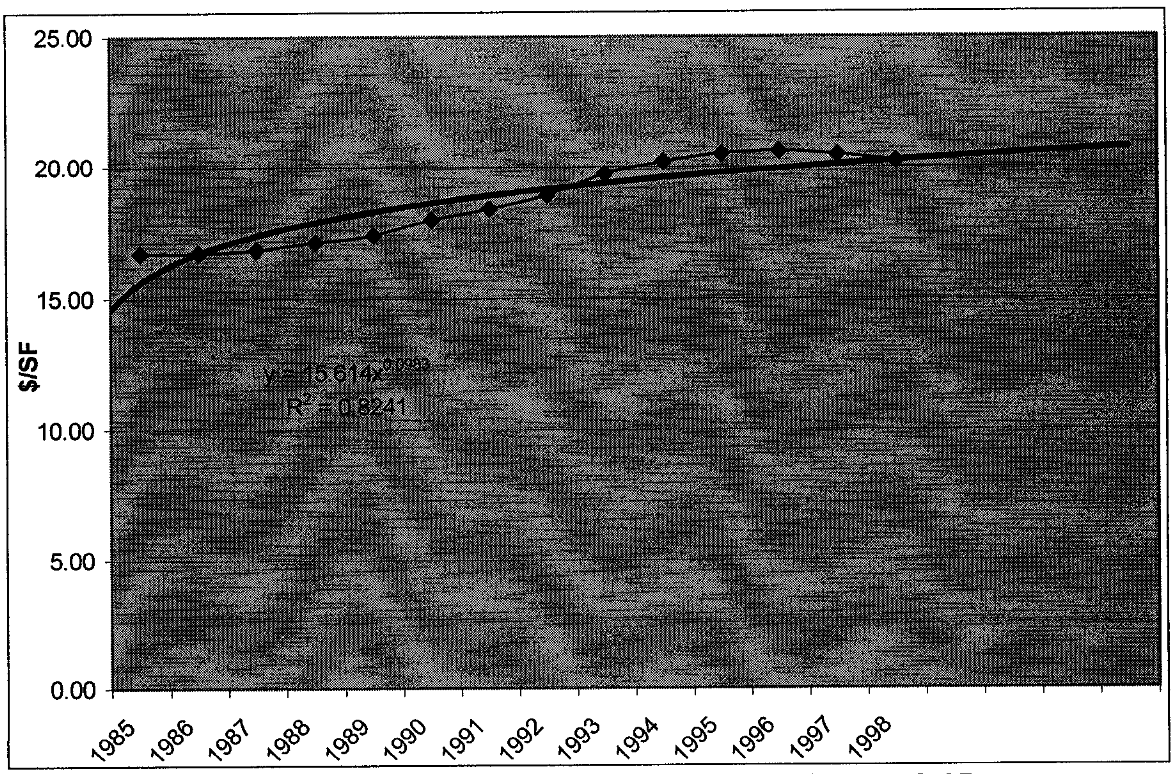

Figure B.8 Smoothed Rental Trend Line for α = 0.15

4) for α = 0.20

Table B-16 Smoothed Forecast for α = 0.20

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.2	3.33	0.80	16.72	13.37	16.70
1986	17.52	16.79	0.2	3.36	0.80	16.70	13.36	16.72
1987	18.77	17.52	0.2	3.50	0.80	16.72	13.38	16.88
1988	18.95	18.77	0.2	3.75	0.80	16.88	13.50	17.26
1989	21.32	18.95	0.2	3.79	0.80	17.26	13.81	17.60
1990	20.68	21.32	0.2	4.26	0.80	17.60	14.08	18.34
1991	21.84	20.68	0.2	4.14	0.80	18.34	14.67	18.81
1992	24.26	21.84	0.2	4.37	0.80	18.81	15.05	19.41
1993	22.89	24.26	0.2	4.85	0.80	19.41	15.53	20.38
1994	22.26	22.89	0.2	4.58	0.80	20.38	16.31	20.88
1995	21.08	22.26	0.2	4.45	0.80	20.88	16.71	21.16
1996	19.79	21.08	0.2	4.22	0.80	21.16	16.93	21.14
1997	18.80	19.79	0.2	3.96	0.80	21.14	16.91	20.87
1998		18.80	0.2	3.76	0.80	20.87	16.70	20.46

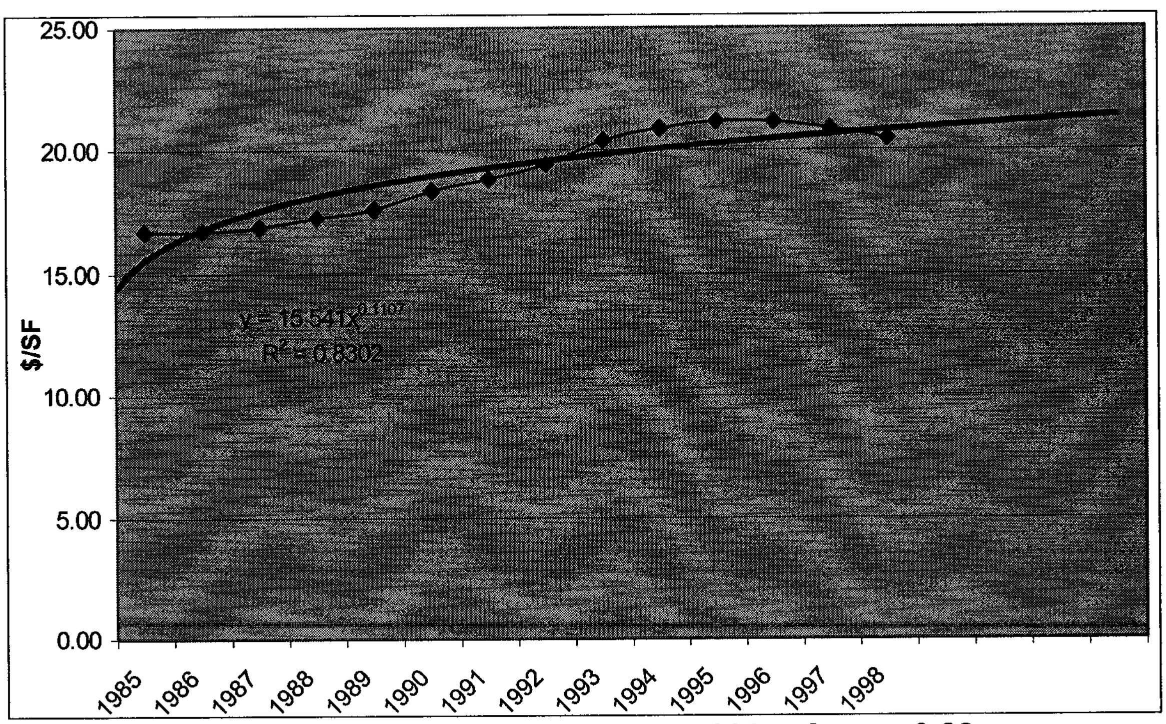

Figure B.9 Smoothed Rental Trend Line for α = 0.20

5) for α = 0.25

Table B-17 Smoothed Forecast for α = 0.25

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.25	4.16	0.75	16.72	12.54	16.70
1986	17.52	16.79	0.25	4.20	0.75	16.70	12.53	16.72
1987	18.77	17.52	0.25	4.38	0.75	16.72	12.54	16.92
1988	18.95	18.77	0.25	4.69	0.75	16.92	12.69	17.38
1989	21.32	18.95	0.25	4.74	0.75	17.38	13.04	17.78
1990	20.68	21.32	0.25	5.33	0.75	17.78	13.33	18.66
1991	21.84	20.68	0.25	5.17	0.75	18.66	14.00	19.17
1992	24.26	21.84	0.25	5.46	0.75	19.17	14.37	19.83
1993	22.89	24.26	0.25	6.06	0.75	19.83	14.87	20.94
1994	22.26	22.89	0.25	5.72	0.75	20.94	15.70	21.43
1995	21.08	22.26	0.25	5.56	0.75	21.43	16.07	21.63
1996	19.79	21.08	0.25	5.27	0.75	21.63	16.22	21.50
1997	18.80	19.79	0.25	4.95	0.75	21.50	16.12	21.07
1998		18.80	0.25	4.70	0.75	21.07	15.80	20.50

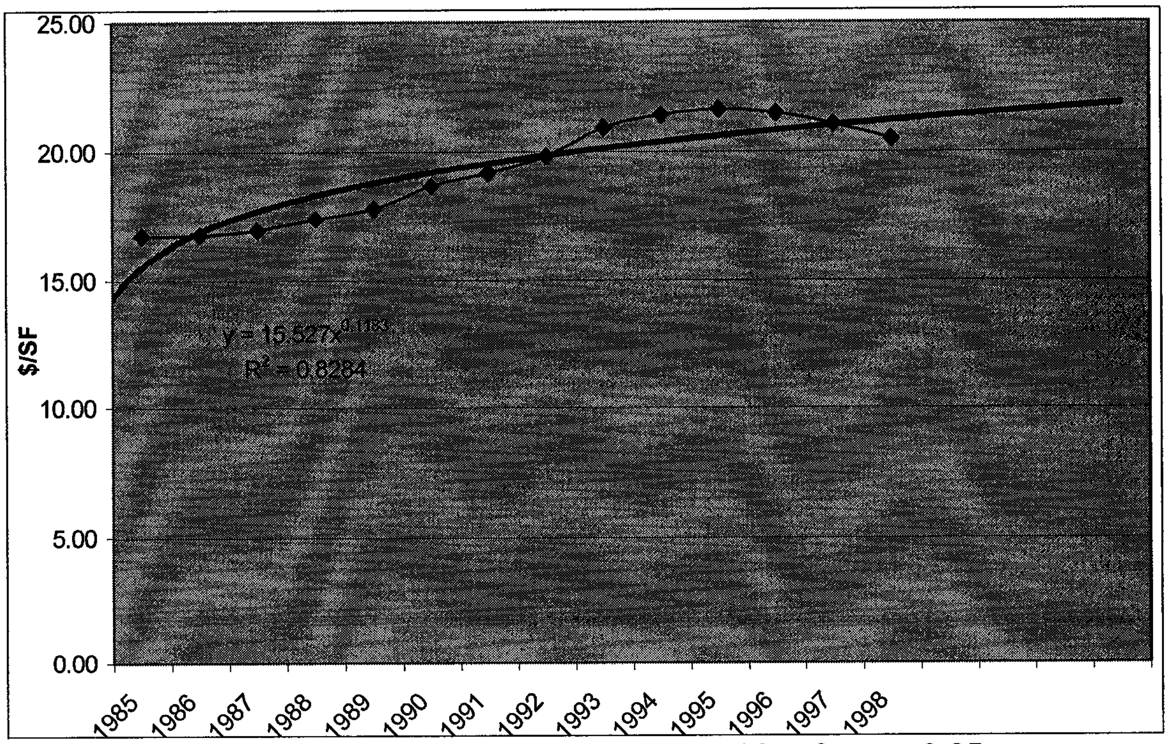

Figure B.10 Smoothed Rental Trend Line for α = 0.25

6) for $\alpha = 0.30$

Table B-18 Smoothed Forecast for $\alpha = 0.30$

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	$(1-\alpha)$ (5)	Previous Forecast of Last Year's Value (6)	$(\alpha - 1)$ (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.3	5.00	0.70	16.72	11.70	16.70
1986	17.52	16.79	0.3	5.04	0.70	16.70	11.69	16.72
1987	18.77	17.52	0.3	5.26	0.70	16.72	11.71	16.96
1988	18.95	18.77	0.3	5.63	0.70	16.96	11.87	17.50
1989	21.32	18.95	0.3	5.69	0.70	17.50	12.25	17.94
1990	20.68	21.32	0.3	6.39	0.70	17.94	12.56	18.95
1991	21.84	20.68	0.3	6.20	0.70	18.95	13.27	19.47
1992	24.26	21.84	0.3	6.55	0.70	19.47	13.63	20.18
1993	22.89	24.26	0.3	7.28	0.70	20.18	14.13	21.40
1994	22.26	22.89	0.3	6.87	0.70	21.40	14.98	21.85
1995	21.08	22.26	0.3	6.68	0.70	21.85	15.29	21.97
1996	19.79	21.08	0.3	6.33	0.70	21.97	15.38	21.70
1997	18.80	19.79	0.3	5.94	0.70	21.70	15.19	21.13
1998		18.80	0.3	5.64	0.70	21.13	14.79	20.43

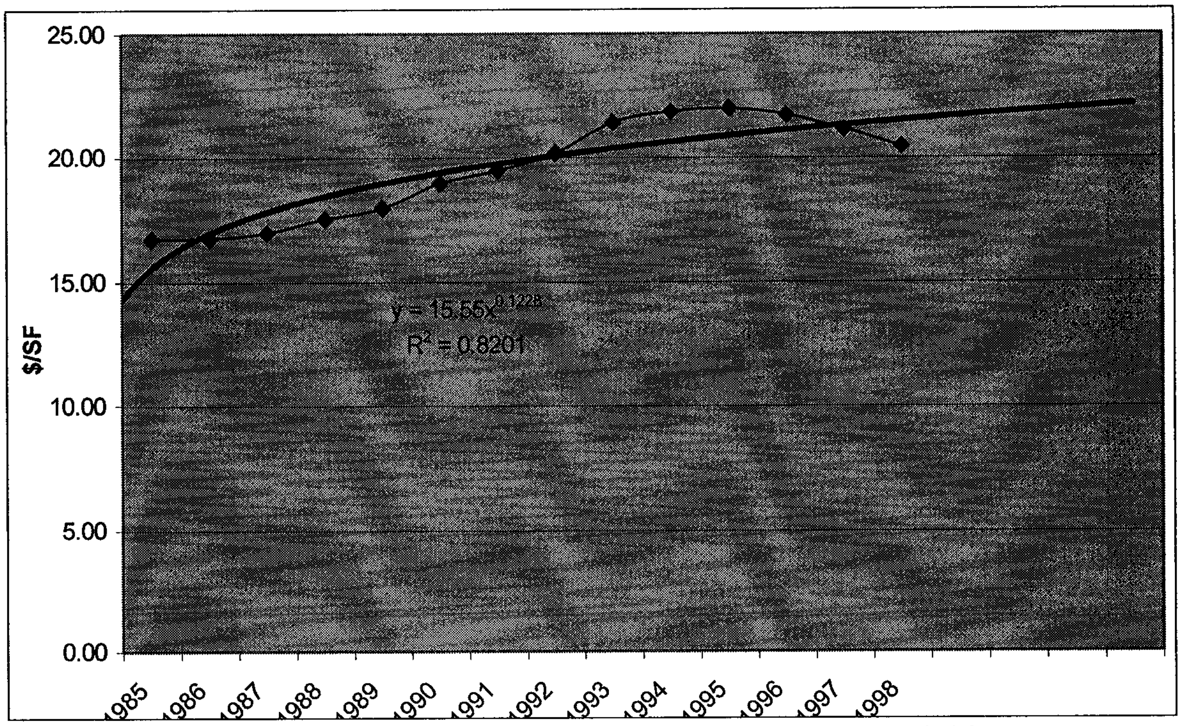

Figure B.11 Smoothed Rental Trend Line for $\alpha = 0.30$

7) for α = 0.35

Table B-19 Smoothed Forecast for α = 0.35

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.35	5.83	0.65	16.72	10.87	16.69
1986	17.52	16.79	0.35	5.87	0.65	16.69	10.85	16.73
1987	18.77	17.52	0.35	6.13	0.65	16.73	10.87	17.00
1988	18.95	18.77	0.35	6.57	0.65	17.00	11.05	17.62
1989	21.32	18.95	0.35	6.63	0.65	17.62	11.45	18.09
1990	20.68	21.32	0.35	7.46	0.65	18.09	11.76	19.22
1991	21.84	20.68	0.35	7.24	0.65	19.22	12.49	19.73
1992	24.26	21.84	0.35	7.64	0.65	19.73	12.82	20.47
1993	22.89	24.26	0.35	8.49	0.65	20.47	13.30	21.79
1994	22.26	22.89	0.35	8.01	0.65	21.79	14.17	22.18
1995	21.08	22.26	0.35	7.79	0.65	22.18	14.41	22.20
1996	19.79	21.08	0.35	7.38	0.65	22.20	14.43	21.81
1997	18.80	19.79	0.35	6.93	0.65	21.81	14.18	21.10
1998		18.80	0.35	6.58	0.65	21.10	13.72	20.30

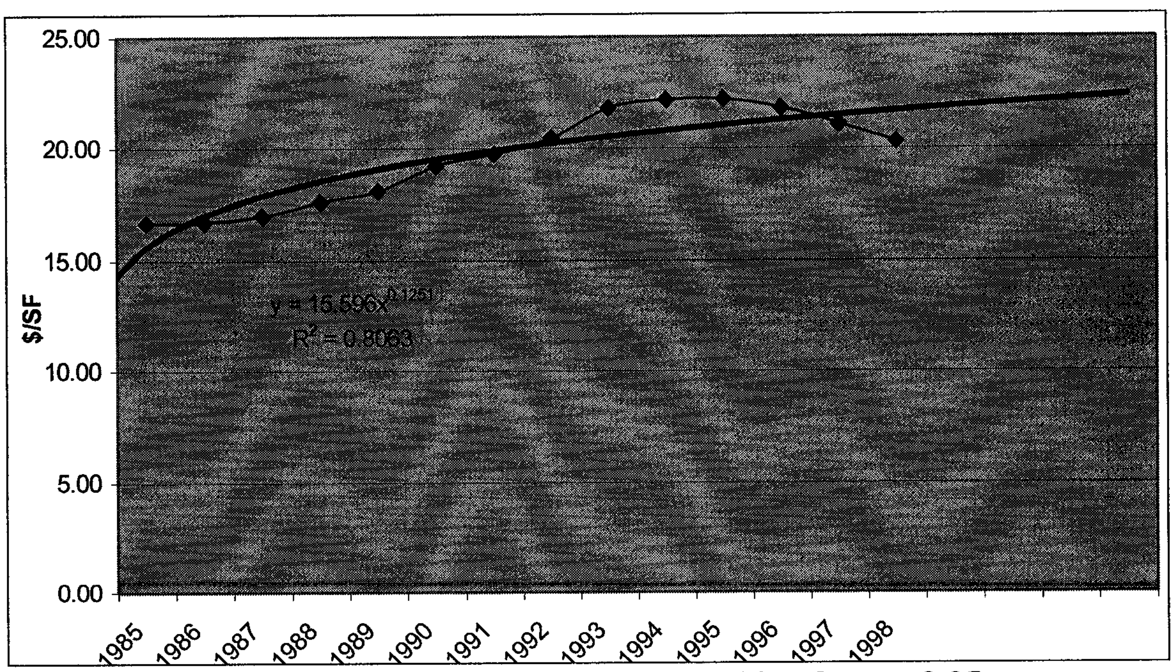

Figure B.12 Smoothed Rental Trend Line for α = 0.35

8) for $\alpha = 0.40$

Table B-19 Smoothed Forecast for $\alpha = 0.40$

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	$(1-\alpha)$ (5)	Previous Forecast of Last Year's Value (6)	$(\alpha - 1)$ (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.4	6.66	0.60	16.72	10.03	16.69
1986	17.52	16.79	0.4	6.71	0.60	16.69	10.01	16.73
1987	18.77	17.52	0.4	7.01	0.60	16.73	10.04	17.04
1988	18.95	18.77	0.4	7.51	0.60	17.04	10.23	17.73
1989	21.32	18.95	0.4	7.58	0.60	17.73	10.64	18.22
1990	20.68	21.32	0.4	8.53	0.60	18.22	10.93	19.46
1991	21.84	20.68	0.4	8.27	0.60	19.46	11.68	19.95
1992	24.26	21.84	0.4	8.73	0.60	19.95	11.97	20.70
1993	22.89	24.26	0.4	9.70	0.60	20.70	12.42	22.12
1994	22.26	22.89	0.4	9.15	0.60	22.12	13.27	22.43
1995	21.08	22.26	0.4	8.90	0.60	22.43	13.46	22.36
1996	19.79	21.08	0.4	8.43	0.60	22.36	13.42	21.85
1997	18.80	19.79	0.4	7.92	0.60	21.85	13.11	21.03
1998		18.80	0.4	7.52	0.60	21.03	12.62	20.14

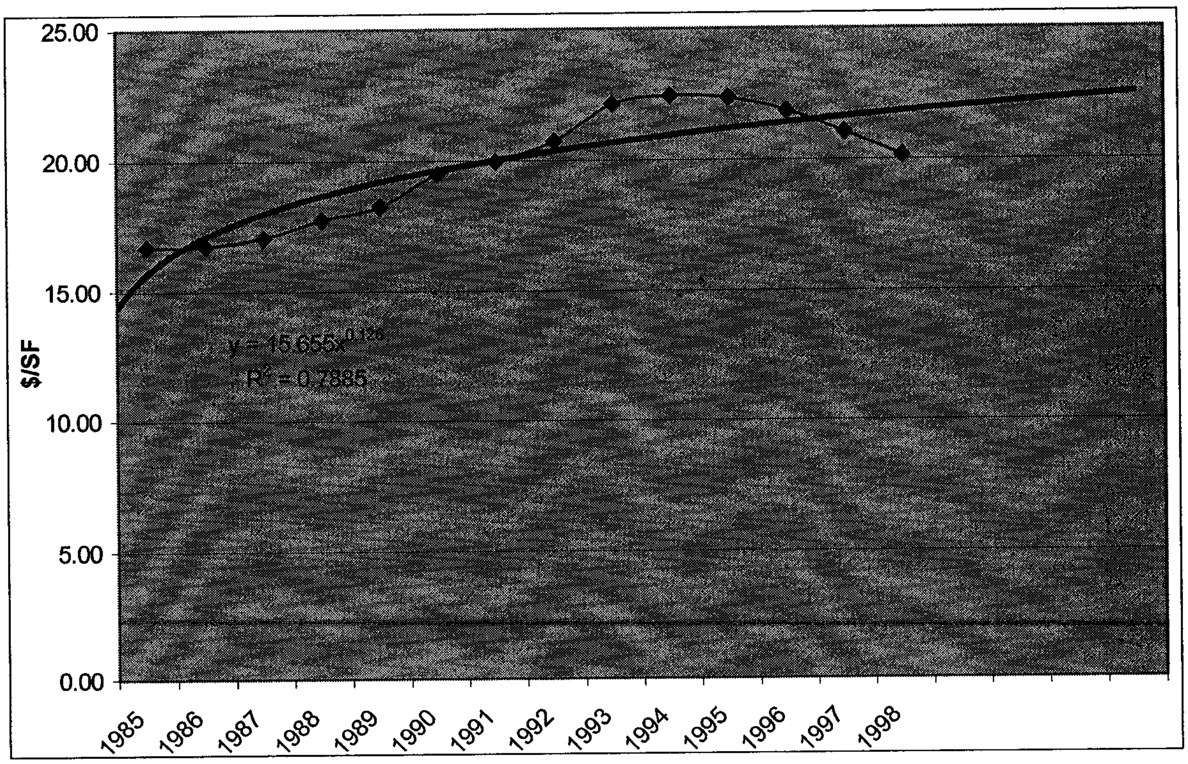

Figure B.13 Smoothed Rental Trend Line for $\alpha = 0.40$

9) for $\alpha = 0.45$

Table B-20 Smoothed Forecast for $\alpha = 0.45$

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	$(1-\alpha)$ (5)	Previous Forecast of Last Year's Value (6)	$(\alpha - 1)$ (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.45	7.49	0.55	16.72	9.19	16.69
1986	17.52	16.79	0.45	7.55	0.55	16.69	9.18	16.73
1987	18.77	17.52	0.45	7.88	0.55	16.73	9.20	17.08
1988	18.95	18.77	0.45	8.45	0.55	17.08	9.40	17.84
1989	21.32	18.95	0.45	8.53	0.55	17.84	9.81	18.34
1990	20.68	21.32	0.45	9.59	0.55	18.34	10.09	19.68
1991	21.84	20.68	0.45	9.31	0.55	19.68	10.82	20.13
1992	24.26	21.84	0.45	9.83	0.55	20.13	11.07	20.90
1993	22.89	24.26	0.45	10.92	0.55	20.90	11.49	22.41
1994	22.26	22.89	0.45	10.30	0.55	22.41	12.32	22.62
1995	21.08	22.26	0.45	10.02	0.55	22.62	12.44	22.46
1996	19.79	21.08	0.45	9.49	0.55	22.46	12.35	21.84
1997	18.80	19.79	0.45	8.91	0.55	21.84	12.01	20.92
1998		18.80	0.45	8.46	0.55	20.92	11.50	19.96

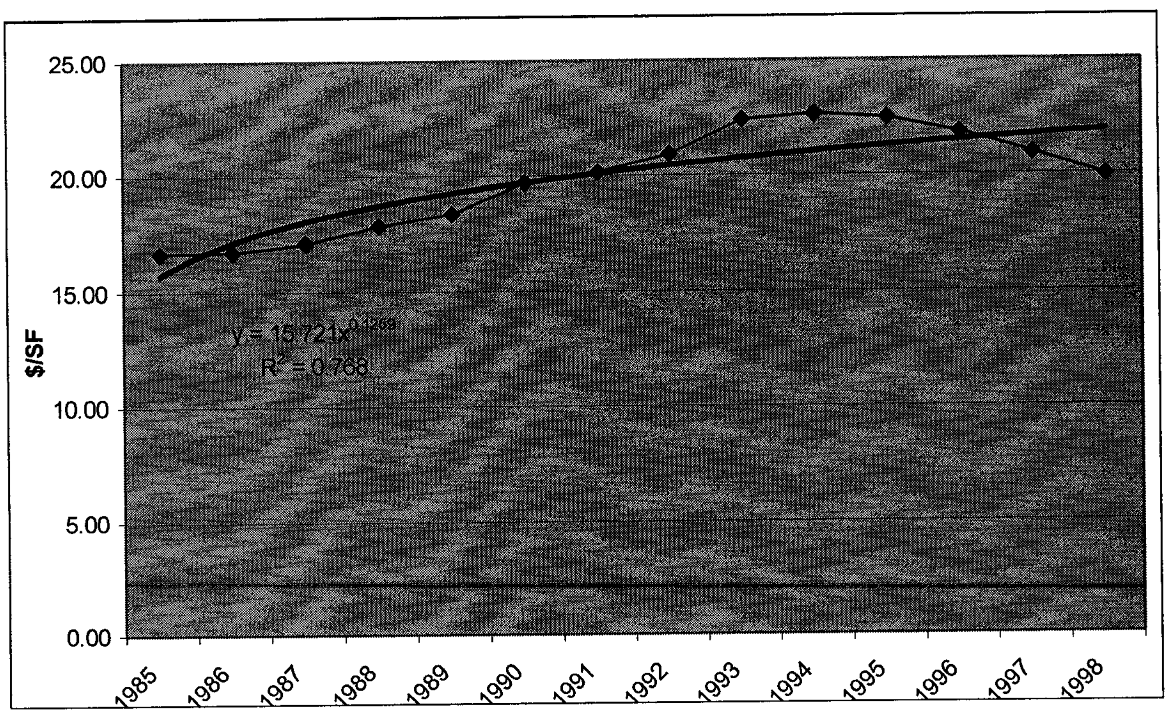

Figure B.14 Smoothed Rental Trend Line for $\alpha = 0.45$

10) for $\alpha = 0.50$

Table B-21 Smoothed Forecast for $\alpha = 0.50$

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	($1-\alpha$) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.5	8.33	0.50	16.72	8.36	16.68
1986	17.52	16.79	0.5	8.39	0.50	16.68	8.34	16.73
1987	18.77	17.52	0.5	8.76	0.50	16.73	8.37	17.13
1988	18.95	18.77	0.5	9.39	0.50	17.13	8.56	17.95
1989	21.32	18.95	0.5	9.48	0.50	17.95	8.97	18.45
1990	20.68	21.32	0.5	10.66	0.50	18.45	9.23	19.88
1991	21.84	20.68	0.5	10.34	0.50	19.88	9.94	20.28
1992	24.26	21.84	0.5	10.92	0.50	20.28	10.14	21.06
1993	22.89	24.26	0.5	12.13	0.50	21.06	10.53	22.66
1994	22.26	22.89	0.5	11.44	0.50	22.66	11.33	22.77
1995	21.08	22.26	0.5	11.13	0.50	22.77	11.39	22.51
1996	19.79	21.08	0.5	10.54	0.50	22.51	11.26	21.80
1997	18.80	19.79	0.5	9.90	0.50	21.80	10.90	20.79
1998		18.80	0.5	9.40	0.50	20.79	10.40	19.80

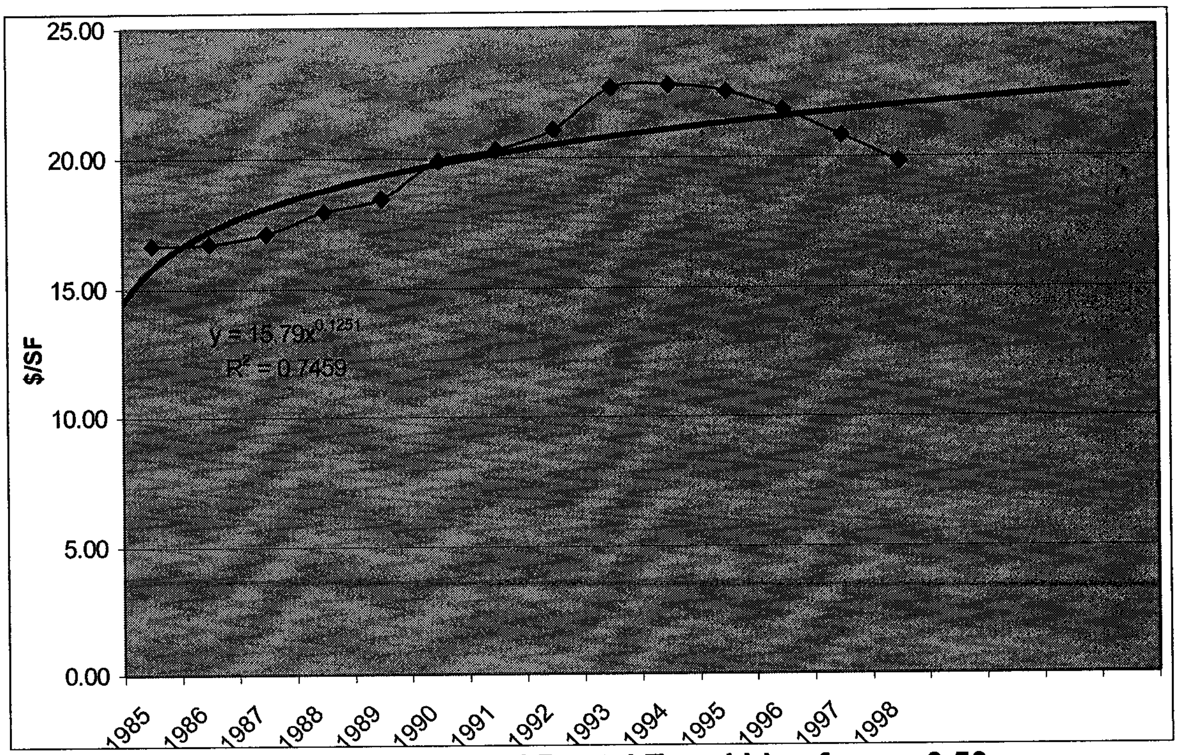

Figure B.15 Smoothed Rental Trend Line for $\alpha = 0.50$

11) for α = 0.55

Table B-22 Smoothed Forecast for α = 0.55

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.55	9.16	0.45	16.72	7.52	16.68
1986	17.52	16.79	0.55	9.23	0.45	16.68	7.51	16.74
1987	18.77	17.52	0.55	9.63	0.45	16.74	7.53	17.17
1988	18.95	18.77	0.55	10.32	0.45	17.17	7.72	18.05
1989	21.32	18.95	0.55	10.42	0.45	18.05	8.12	18.55
1990	20.68	21.32	0.55	11.72	0.45	18.55	8.35	20.07
1991	21.84	20.68	0.55	11.37	0.45	20.07	9.03	20.41
1992	24.26	21.84	0.55	12.01	0.45	20.41	9.18	21.19
1993	22.89	24.26	0.55	13.34	0.45	21.19	9.54	22.88
1994	22.26	22.89	0.55	12.59	0.45	22.88	10.29	22.88
1995	21.08	22.26	0.55	12.24	0.45	22.88	10.30	22.54
1996	19.79	21.08	0.55	11.60	0.45	22.54	10.14	21.74
1997	18.80	19.79	0.55	10.88	0.45	21.74	9.78	20.67
1998		18.80	0.55	10.34	0.45	20.67	9.30	19.64

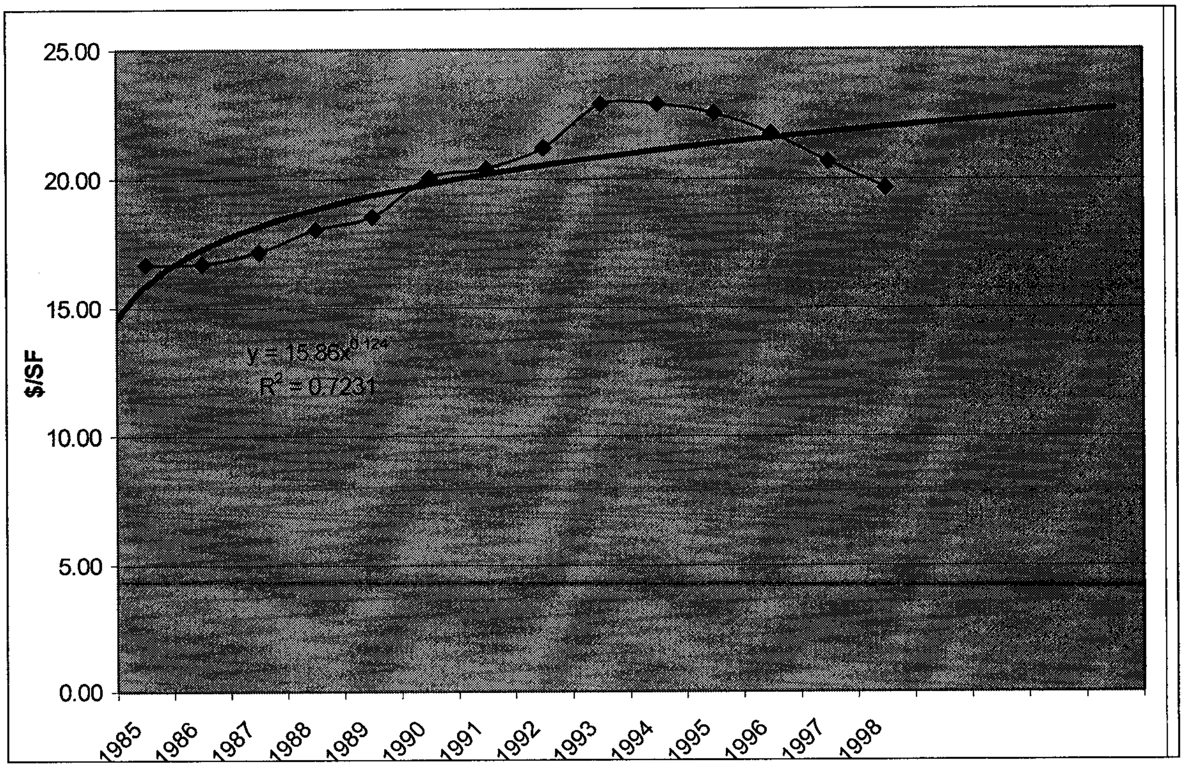

Figure B.16 Smoothed Rental Trend Line for α = 0.55

12) for $\alpha = 0.60$

Table B-23 Smoothed Forecast for $\alpha = 0.60$

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.6	9.99	0.40	16.72	6.69	16.68
1986	17.52	16.79	0.6	10.07	0.40	16.68	6.67	16.74
1987	18.77	17.52	0.6	10.51	0.40	16.74	6.70	17.21
1988	18.95	18.77	0.6	11.26	0.40	17.21	6.88	18.14
1989	21.32	18.95	0.6	11.37	0.40	18.14	7.26	18.63
1990	20.68	21.32	0.6	12.79	0.40	18.63	7.45	20.24
1991	21.84	20.68	0.6	12.41	0.40	20.24	8.10	20.50
1992	24.26	21.84	0.6	13.10	0.40	20.50	8.20	21.30
1993	22.89	24.26	0.6	14.55	0.40	21.30	8.52	23.07
1994	22.26	22.89	0.6	13.73	0.40	23.07	9.23	22.96
1995	21.08	22.26	0.6	13.35	0.40	22.96	9.18	22.54
1996	19.79	21.08	0.6	12.65	0.40	22.54	9.02	21.67
1997	18.80	19.79	0.6	11.87	0.40	21.67	8.67	20.54
1998		18.80	0.6	11.28	0.40	20.54	8.22	19.50

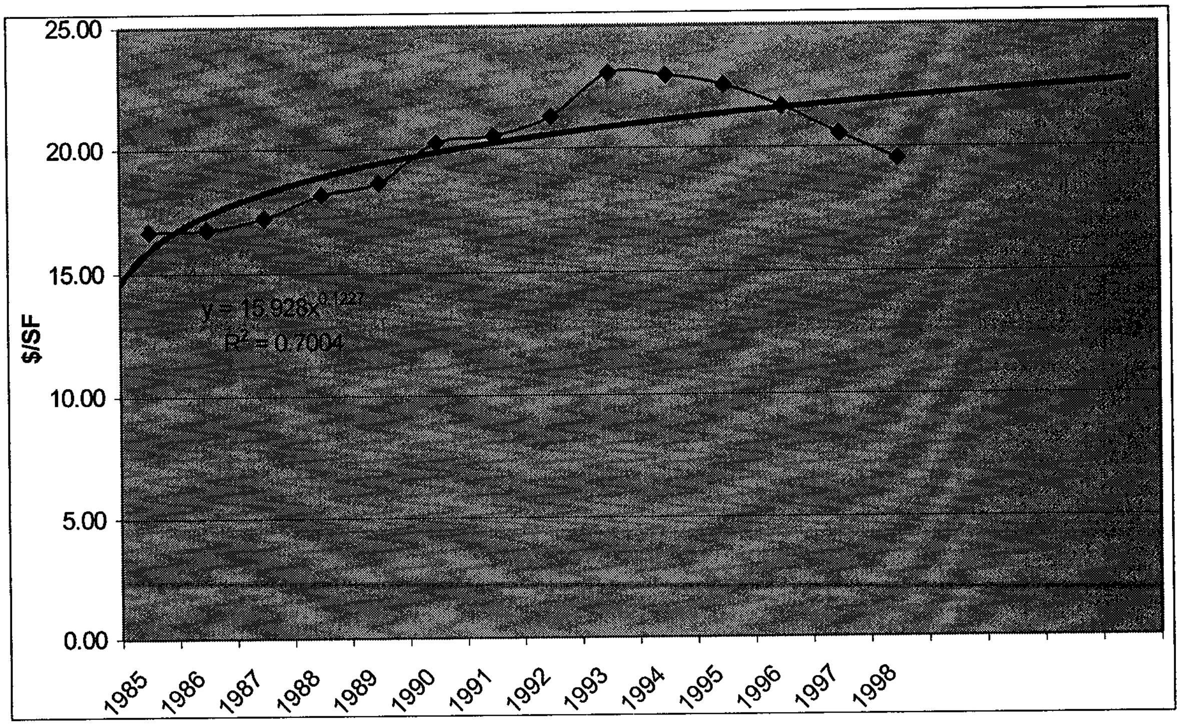

Figure B.17 Smoothed Rental Trend Line for $\alpha = 0.60$

13) for α = 0.65

Table B-24 Smoothed Forecast for α = 0.65

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.65	10.82	0.35	16.72	5.85	16.67
1986	17.52	16.79	0.65	10.91	0.35	16.67	5.84	16.75
1987	18.77	17.52	0.65	11.39	0.35	16.75	5.86	17.25
1988	18.95	18.77	0.65	12.20	0.35	17.25	6.04	18.24
1989	21.32	18.95	0.65	12.32	0.35	18.24	6.38	18.70
1990	20.68	21.32	0.65	13.86	0.35	18.70	6.55	20.40
1991	21.84	20.68	0.65	13.44	0.35	20.40	7.14	20.58
1992	24.26	21.84	0.65	14.19	0.35	20.58	7.20	21.40
1993	22.89	24.26	0.65	15.77	0.35	21.40	7.49	23.26
1994	22.26	22.89	0.65	14.88	0.35	23.26	8.14	23.02
1995	21.08	22.26	0.65	14.47	0.35	23.02	8.06	22.52
1996	19.79	21.08	0.65	13.70	0.35	22.52	7.88	21.59
1997	18.80	19.79	0.65	12.86	0.35	21.59	7.56	20.42
1998		18.80	0.65	12.22	0.35	20.42	7.15	19.37

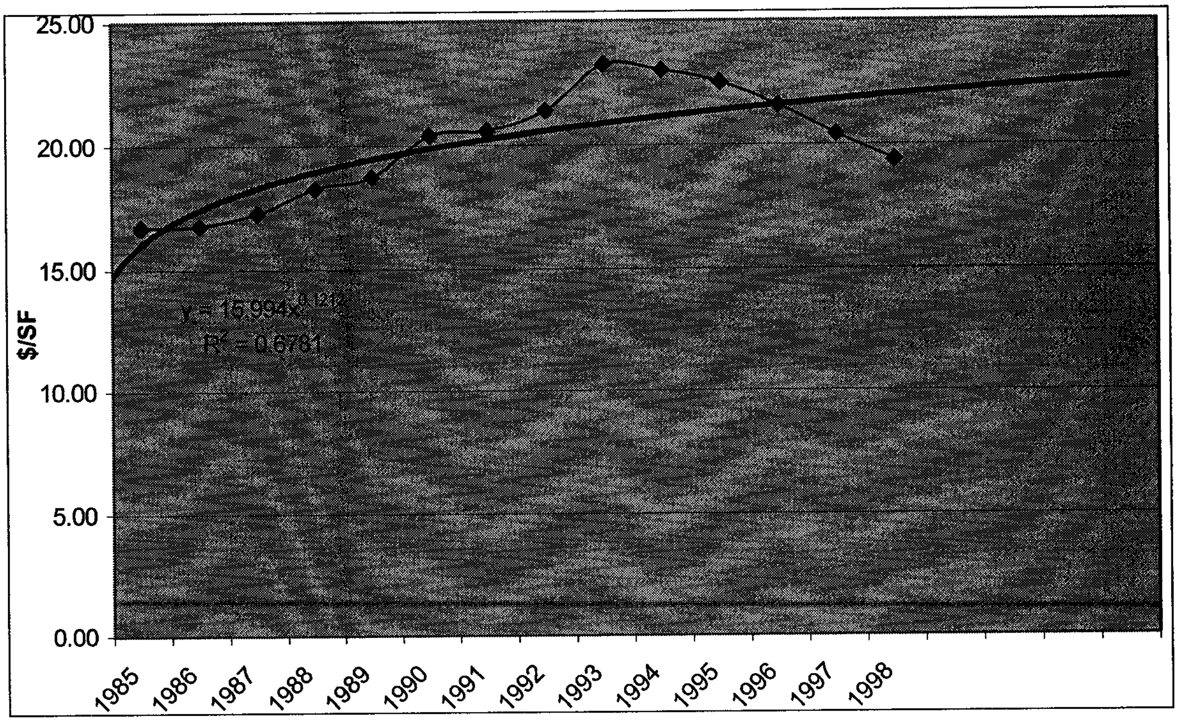

Figure B.18 Smoothed Rental Trend Line for α = 0.65

14) for α = 0.70

Table B-25 Smoothed Forecast for α = 0.70

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.7	11.66	0.30	16.72	5.02	16.67
1986	17.52	16.79	0.7	11.75	0.30	16.67	5.00	16.75
1987	18.77	17.52	0.7	12.26	0.30	16.75	5.03	17.29
1988	18.95	18.77	0.7	13.14	0.30	17.29	5.19	18.33
1989	21.32	18.95	0.7	13.27	0.30	18.33	5.50	18.76
1990	20.68	21.32	0.7	14.92	0.30	18.76	5.63	20.55
1991	21.84	20.68	0.7	14.48	0.30	20.55	6.17	20.64
1992	24.26	21.84	0.7	15.28	0.30	20.64	6.19	21.48
1993	22.89	24.26	0.7	16.98	0.30	21.48	6.44	23.42
1994	22.26	22.89	0.7	16.02	0.30	23.42	7.03	23.05
1995	21.08	22.26	0.7	15.58	0.30	23.05	6.91	22.49
1996	19.79	21.08	0.7	14.76	0.30	22.49	6.75	21.51
1997	18.80	19.79	0.7	13.85	0.30	21.51	6.45	20.31
1998		18.80	0.7	13.16	0.30	20.31	6.09	19.25

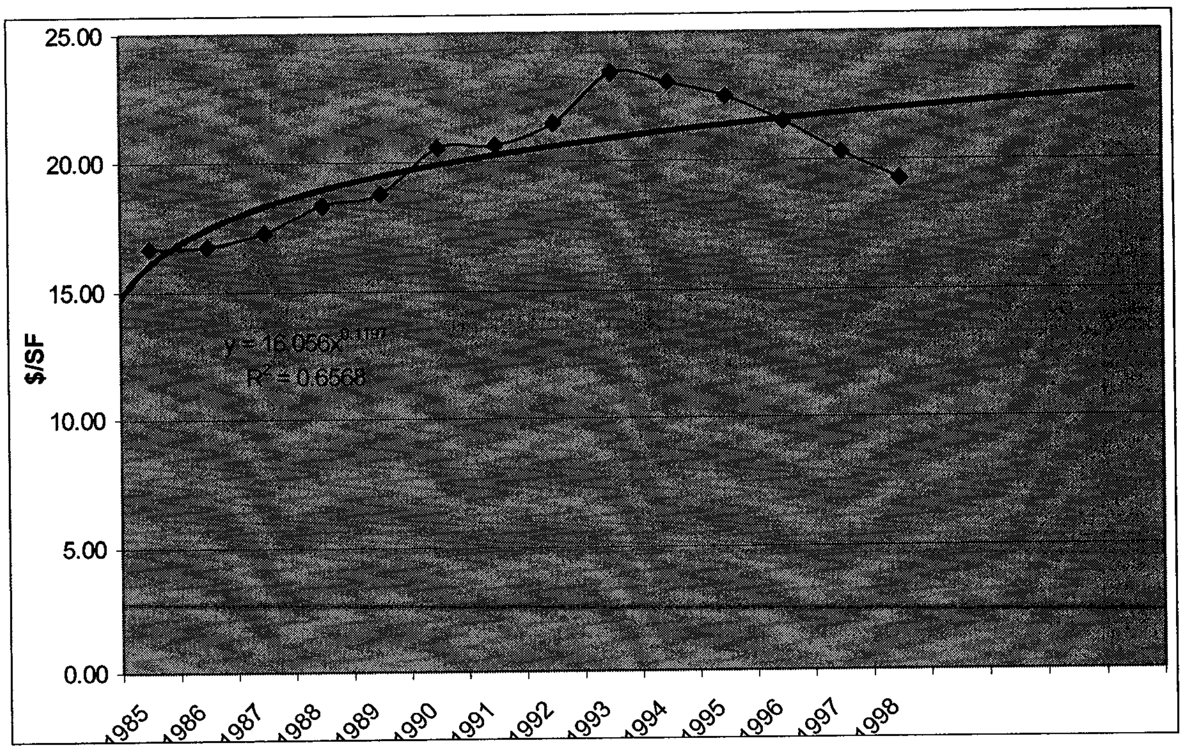

Figure B.19 Smoothed Rental Trend Line for α = 0.70

15) for $\alpha = 0.75$

Table B-26 Smoothed Forecast for α = 0.75

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.75	12.49	0.25	16.72	4.18	16.67
1986	17.52	16.79	0.75	12.59	0.25	16.67	4.17	16.76
1987	18.77	17.52	0.75	13.14	0.25	16.76	4.19	17.33
1988	18.95	18.77	0.75	14.08	0.25	17.33	4.33	18.41
1989	21.32	18.95	0.75	14.21	0.25	18.41	4.60	18.82
1990	20.68	21.32	0.75	15.99	0.25	18.82	4.70	20.69
1991	21.84	20.68	0.75	15.51	0.25	20.69	5.17	20.68
1992	24.26	21.84	0.75	16.38	0.25	20.68	5.17	21.55
1993	22.89	24.26	0.75	18.19	0.25	21.55	5.39	23.58
1994	22.26	22.89	0.75	17.16	0.25	23.58	5.89	23.06
1995	21.08	22.26	0.75	16.69	0.25	23.06	5.76	22.46
1996	19.79	21.08	0.75	15.81	0.25	22.46	5.61	21.43
1997	18.80	19.79	0.75	14.84	0.25	21.43	5.36	20.20
1998		18.80	0.75	14.10	0.25	20.20	5.05	19.15

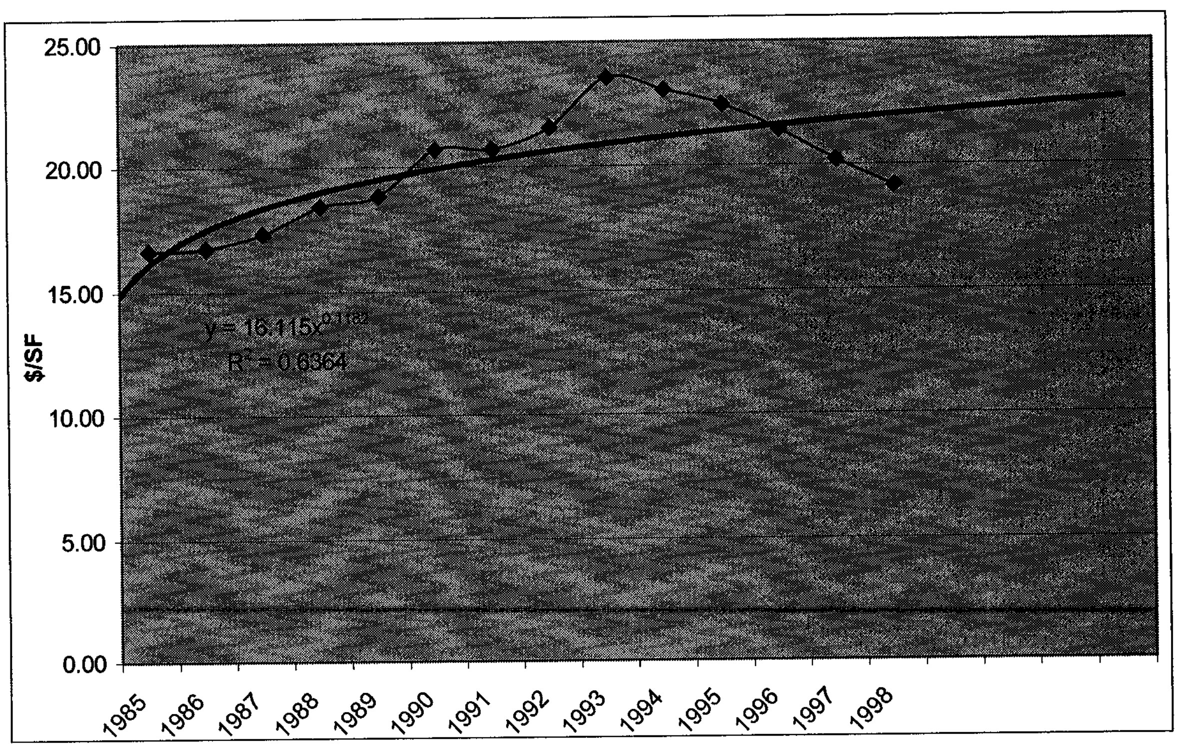

Figure B.20 Smoothed Rental Trend Line for α = 0.75

16) for α = 0.80

Table B-27 Smoothed Forecast for α = 080

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.8	13.32	0.20	16.72	3.34	16.66
1986	17.52	16.79	0.8	13.43	0.20	16.66	3.33	16.76
1987	18.77	17.52	0.8	14.01	0.20	16.76	3.35	17.37
1988	18.95	18.77	0.8	15.02	0.20	17.37	3.47	18.49
1989	21.32	18.95	0.8	15.16	0.20	18.49	3.70	18.86
1990	20.68	21.32	0.8	17.05	0.20	18.86	3.77	20.82
1991	21.84	20.68	0.8	16.54	0.20	20.82	4.16	20.71
1992	24.26	21.84	0.8	17.47	0.20	20.71	4.14	21.61
1993	22.89	24.26	0.8	19.40	0.20	21.61	4.32	23.73
1994	22.26	22.89	0.8	18.31	0.20	23.73	4.75	23.05
1995	21.08	22.26	0.8	17.80	0.20	23.05	4.61	22.42
1996	19.79	21.08	0.8	16.87	0.20	22.42	4.48	21.35
1997	18.80	19.79	0.8	15.83	0.20	21.35	4.27	20.10
1998		18.80	0.8	15.04	0.20	20.10	4.02	19.06

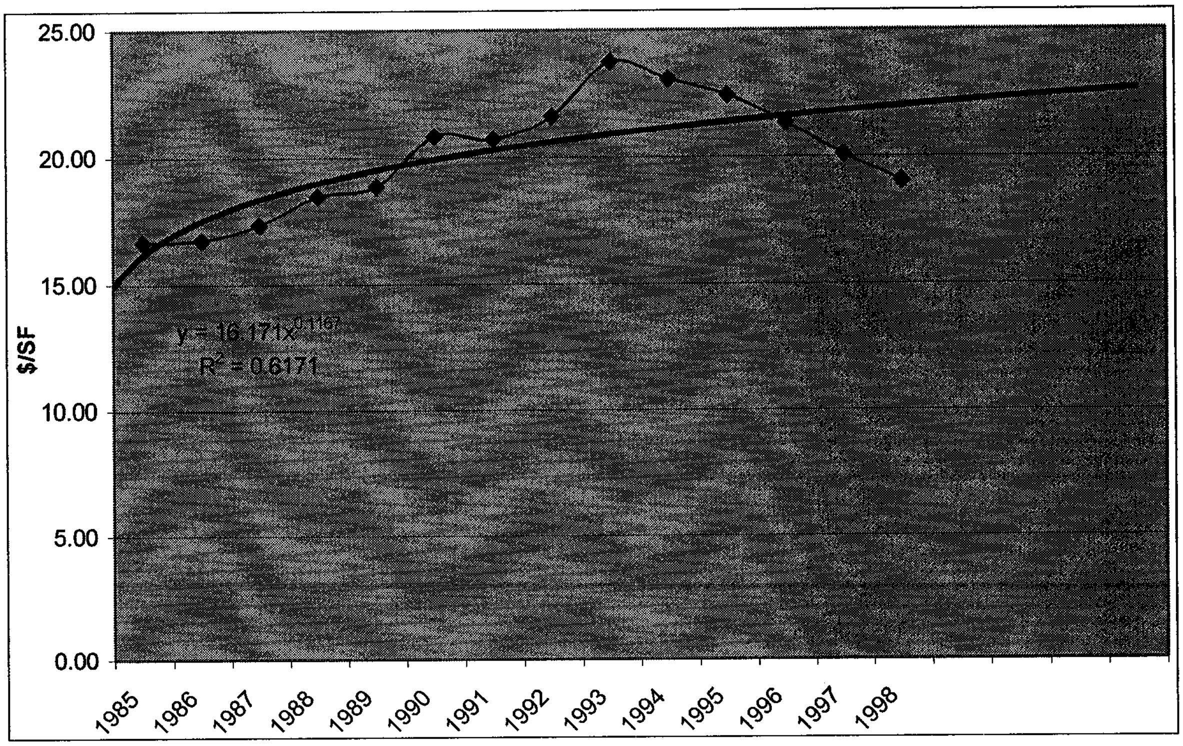

Figure B.21 Smoothed Rental Trend Line for α = 0.80

17) for α = 0.85

Table B-28 Smoothed Forecast for α = 085

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.85	14.15	0.15	16.72	2.51	16.66
1986	17.52	16.79	0.85	14.27	0.15	16.66	2.50	16.77
1987	18.77	17.52	0.85	14.89	0.15	16.77	2.51	17.40
1988	18.95	18.77	0.85	15.95	0.15	17.40	2.61	18.57
1989	21.32	18.95	0.85	16.11	0.15	18.57	2.78	18.89
1990	20.68	21.32	0.85	18.12	0.15	18.89	2.83	20.95
1991	21.84	20.68	0.85	17.58	0.15	20.95	3.14	20.72
1992	24.26	21.84	0.85	18.56	0.15	20.72	3.11	21.67
1993	22.89	24.26	0.85	20.62	0.15	21.67	3.25	23.87
1994	22.26	22.89	0.85	19.45	0.15	23.87	3.58	23.03
1995	21.08	22.26	0.85	18.92	0.15	23.03	3.45	22.37
1996	19.79	21.08	0.85	17.92	0.15	22.37	3.36	21.28
1997	18.80	19.79	0.85	16.82	0.15	21.28	3.19	20.01
1998		18.80	0.85	15.98	0.15	20.01	3.00	18.98

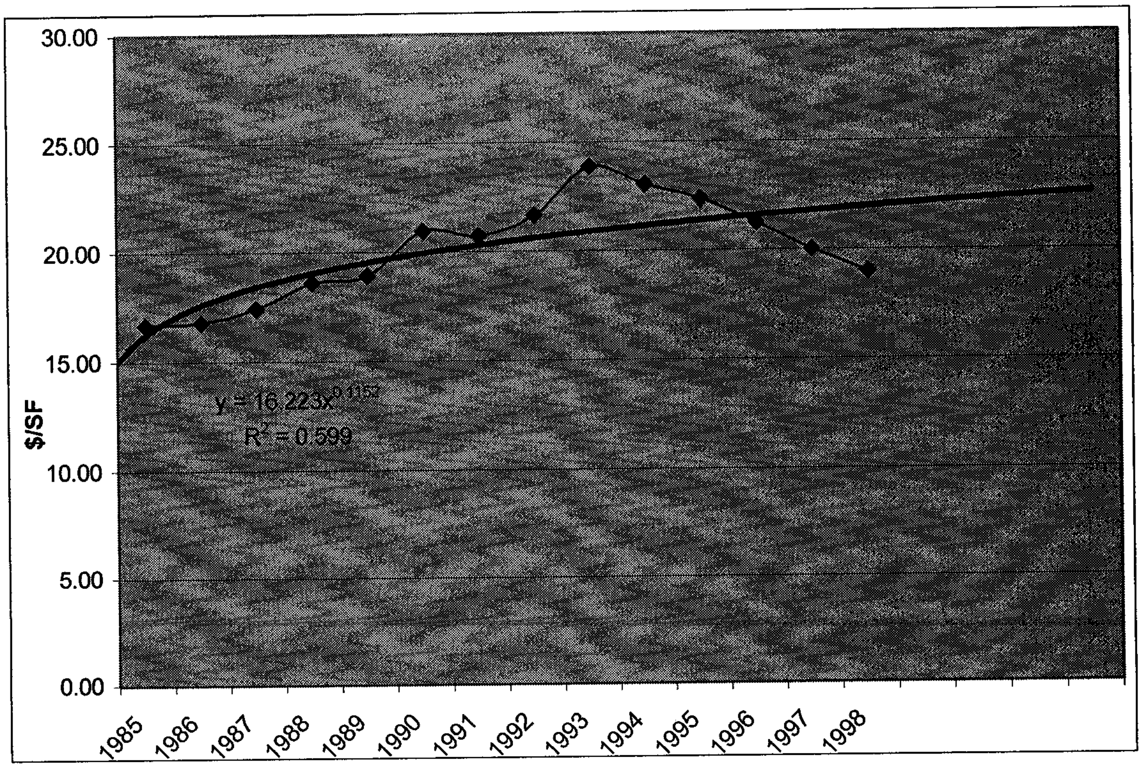

Figure B.22 Smoothed Rental Trend Line for α = 0.85

18) for $\alpha = 0.90$

Table B-29 Smoothed Forecast for α = 090

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.9	14.99	0.10	16.72	1.67	16.66
1986	17.52	16.79	0.9	15.11	0.10	16.66	1.67	16.77
1987	18.77	17.52	0.9	15.77	0.10	16.77	1.68	17.44
1988	18.95	18.77	0.9	16.89	0.10	17.44	1.74	18.64
1989	21.32	18.95	0.9	17.06	0.10	18.64	1.86	18.92
1990	20.68	21.32	0.9	19.18	0.10	18.92	1.89	21.08
1991	21.84	20.68	0.9	18.61	0.10	21.08	2.11	20.72
1992	24.26	21.84	0.9	19.65	0.10	20.72	2.07	21.72
1993	22.89	24.26	0.9	21.83	0.10	21.72	2.17	24.00
1994	22.26	22.89	0.9	20.60	0.10	24.00	2.40	23.00
1995	21.08	22.26	0.9	20.03	0.10	23.00	2.30	22.33
1996	19.79	21.08	0.9	18.98	0.10	22.33	2.23	21.21
1997	18.80	19.79	0.9	17.81	0.10	21.21	2.12	19.93
1998		18.80	0.9	16.92	0.10	19.93	1.99	18.91

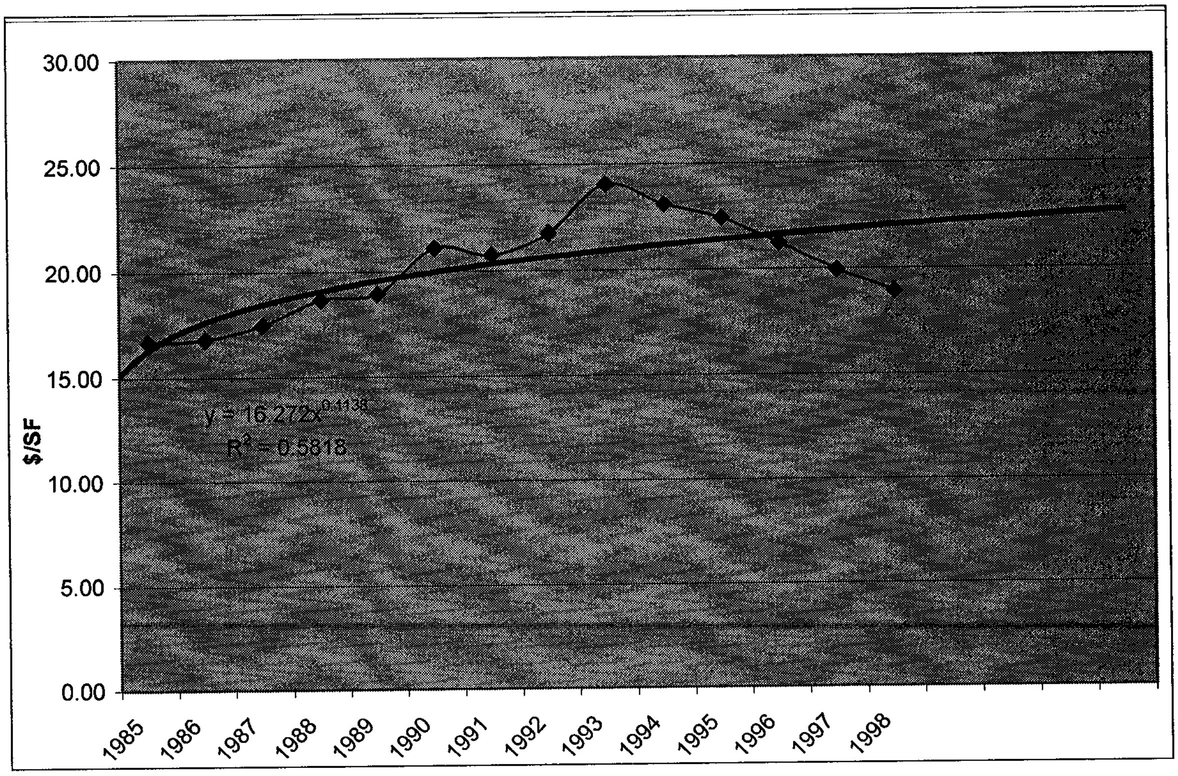

Figure B.23 Smoothed Rental Trend Line for α = 0.90

19) for α = 0.95

Table B-30 Smoothed Forecast for α = 095

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	(1-α) (5)	Previous Forecast of Last Year's Value (6)	(α - 1) (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	0.95	15.82	0.05	16.72	0.84	16.65
1986	17.52	16.79	0.95	15.95	0.05	16.65	0.83	16.78
1987	18.77	17.52	0.95	16.64	0.05	16.78	0.84	17.48
1988	18.95	18.77	0.95	17.83	0.05	17.48	0.87	18.71
1989	21.32	18.95	0.95	18.00	0.05	18.71	0.94	18.94
1990	20.68	21.32	0.95	20.25	0.05	18.94	0.95	21.20
1991	21.84	20.68	0.95	19.65	0.05	21.20	1.06	20.71
1992	24.26	21.84	0.95	20.74	0.05	20.71	1.04	21.78
1993	22.89	24.26	0.95	23.04	0.05	21.78	1.09	24.13
1994	22.26	22.89	0.95	21.74	0.05	24.13	1.21	22.95
1995	21.08	22.26	0.95	21.14	0.05	22.95	1.15	22.29
1996	19.79	21.08	0.95	20.03	0.05	22.29	1.11	21.14
1997	18.80	19.79	0.95	18.80	0.05	21.14	1.06	19.86
1998		18.80	0.95	17.86	0.05	19.86	0.99	18.85

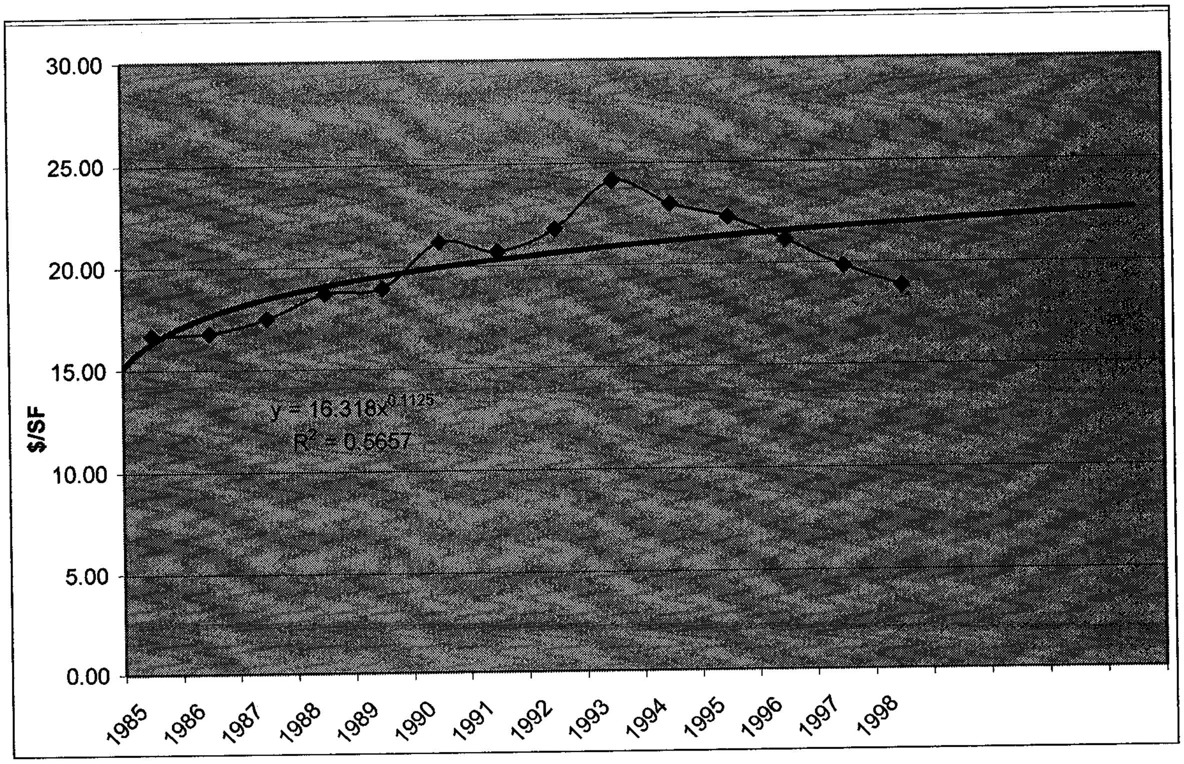

Figure B.24 Smoothed Rental Trend Line for α = 0.95

20) for $\alpha = 1.0$

Table B-31 Smoothed Forecast for $\alpha = 1.0$

Year	Actual Value (2)	Last Year Value (3)	α (4)	α (Last Year Value) (4)*(3)	$(1-\alpha)$ (5)	Previous Forecast of Last Year's Value (6)	$(\alpha - 1)$ (Previous Forecast of Last Year's Value (5)*(6)	Smoothed Forecast (4)(3)+(5)(6)
1984	16.65							
1985	16.79	16.65	1	16.65	0.00	16.72	0.00	16.65
1986	17.52	16.79	1	16.79	0.00	16.65	0.00	16.79
1987	18.77	17.52	1	17.52	0.00	16.79	0.00	17.52
1988	18.95	18.77	1	18.77	0.00	17.52	0.00	18.77
1989	21.32	18.95	1	18.95	0.00	18.77	0.00	18.95
1990	20.68	21.32	1	21.32	0.00	18.95	0.00	21.32
1991	21.84	20.68	1	20.68	0.00	21.32	0.00	20.68
1992	24.26	21.84	1	21.84	0.00	20.68	0.00	21.84
1993	22.89	24.26	1	24.26	0.00	21.84	0.00	24.26
1994	22.26	22.89	1	22.89	0.00	24.26	0.00	22.89
1995	21.08	22.26	1	22.26	0.00	22.89	0.00	22.26
1996	19.79	21.08	1	21.08	0.00	22.26	0.00	21.08
1997	18.80	19.79	1	19.79	0.00	21.08	0.00	19.79
1998		18.80	1	18.80	0.00	19.79	0.00	18.80

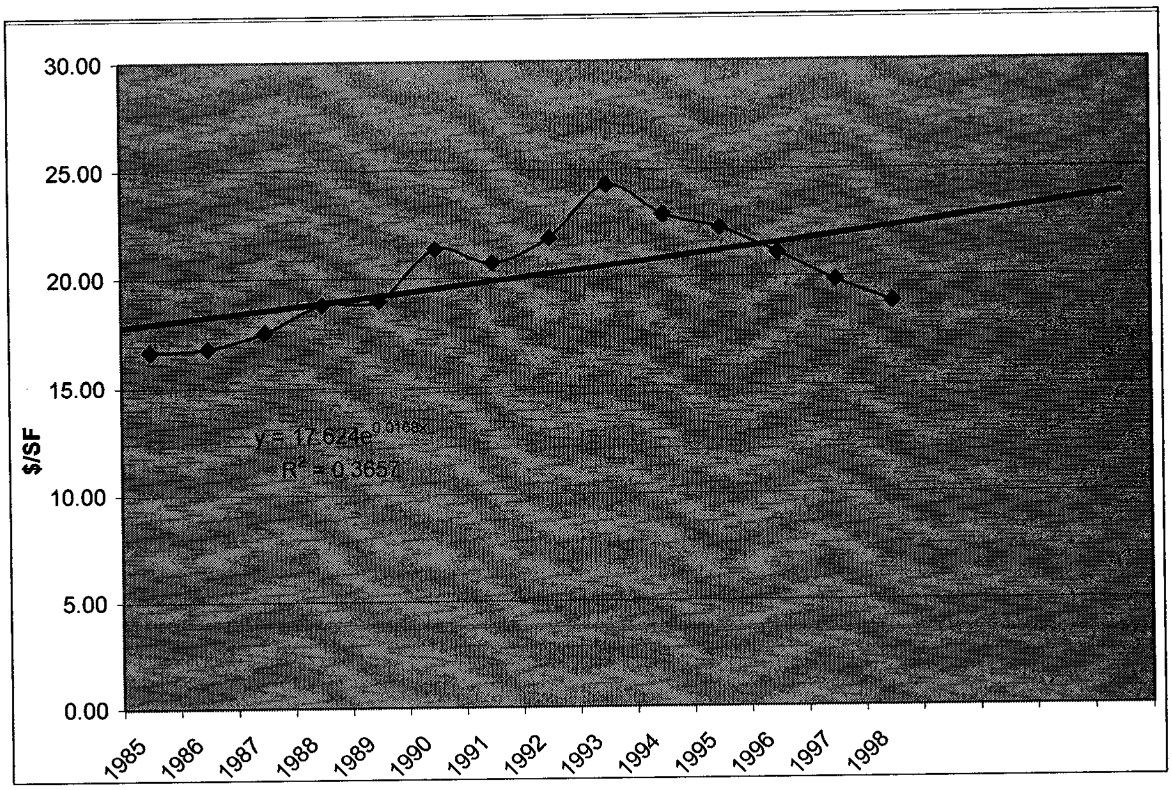

Figure B.25 Smoothed Rental Trend Line for $\alpha = 1.0$

3- Economy-Influenced Forecast

Step 1: in this step the percentage change in the dollar value of the rent as well as the percentage change in the CPI rent values are calculated, and then after these data are plot as illustrated in Table B-32 and Figure B.26. The following expression is used in the calculations:

1. For the Rental Difference: $Y = X_{(i+1)} - X_i$
2. For the Percentage Difference: $Y = \left(\frac{X_{(i+1)}}{X_i}\right) - 1$

Table B-32 Rental Data Comparison

Year	Rental ($/SF) ($X_i$)	Rental Difference $X_{(i+1)}-X_i$	% Rental Difference $[(X_{(i+1)}/X_i)-1]$	CPI-Rent (C_i)	CPI-Rent Difference $C_{(i+1)}-C_i$	% CPI-Rent Difference $[(C_{(i+1)}/C_i)-1]$
1984	16.65			73.4		
1985	16.79	0.14	0.81%	76.5	3.10	4.22%
1986	17.52	0.73	4.36%	79.6	3.10	4.05%
1987	18.77	1.25	7.16%	82.6	3.00	3.77%
1988	19.97	1.20	6.41%	85.9	3.30	4.00%
1989	21.99	2.02	10.11%	90.4	4.50	5.24%
1990	20.85	-1.15	-5.22%	94.1	3.70	4.09%
1991	22.07	1.23	5.88%	97.3	3.20	3.40%
1992	25.72	3.65	16.52%	100.0	2.70	2.77%
1993	23.36	-2.36	-9.16%	102.2	2.20	2.20%
1994	22.22	-1.14	-4.88%	103.9	1.70	1.66%
1995	20.70	-1.52	-6.84%	105.5	1.60	1.54%
1996	19.79	-0.91	-4.40%	106.9	1.40	1.33%
1997	18.80	-0.99	-5.00%	108.1	1.20	1.12%

Correlation R^2=0.6879

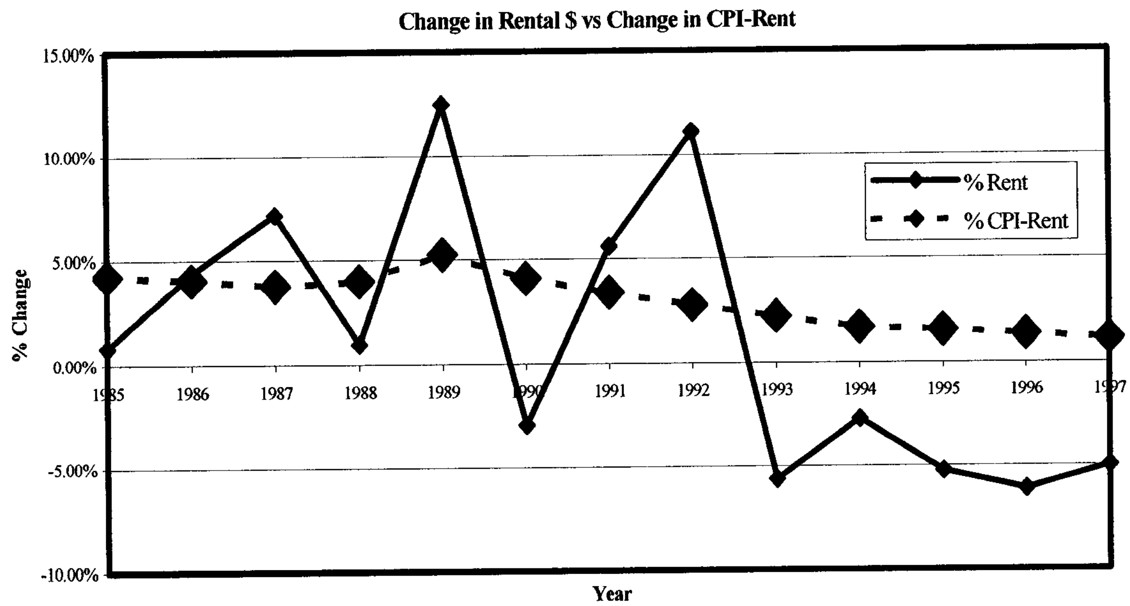

Figure B.26 (%) Change in Rental ($) vs. (%) Change in CPI-Rent

<u>Step 2, 3 and 4</u>: in these steps the actual rental data is used besides the values of the percentage CPI-Rent Difference and the 1984 based year as shown in Table B-33 and Figure B.27.

Table B-33 Rental Forecast Based on % CPI-Rent ($/SF)

Year	Actual Rental (X_i)	% CPI-Rent Difference (D_i)	$W_i=(1+D_i)$	Actual Data Based Forecast $Y_i=X_{(i-1)}*(W_i)$	1984 Actual Data Based Forecast	
1984	16.65					
1985	16.79	4.22%	1.0422	17.35	17.35	=16.65*1.0422
1986	17.52	4.05%	1.0405	17.47	18.06	=17.35*1.0405
1987	18.77	3.77%	1.0377	18.18	18.74	=18.06*1.0377
1988	19.95	4.00%	1.0400	19.52	19.49	=18.74*1.0400
1989	21.32	5.24%	1.0524	19.95	20.51	=19.49*1.0524
1990	20.68	4.09%	1.0409	22.19	21.35	=20.51*1.0409
1991	21.84	3.40%	1.0340	21.38	22.07	=21.35*1.0340
1992	24.26	2.77%	1.0277	22.44	22.68	=22.07*1.0277
1993	22.89	2.20%	1.0220	24.79	23.18	=22.68*1.0220
1994	22.26	1.66%	1.0166	23.27	23.57	=23.57*1.0166
1995	21.08	1.54%	1.0154	22.60	23.93	=23.57*1.0154
1996	19.79	1.33%	1.0133	21.36	24.25	=23.93*1.0133
1997	18.80	1.12%	1.0112	20.01	24.52	=24.25*1.0112
Coefficient of Correlation (Actual vs. Forecast)				0.8588	0.6185	
1998		1.02%	1.0102	18.99	24.77	=24.52*1.0102
1999		0.92%	1.0092	19.17	25.00	=24.77*1.0092
2000		1.09%	1.0109	19.37	25.27	=25.00*1.0109
2001		1.62%	1.0162	19.69	25.68	=25.27*1.0162
2002		1.94%	1.0194	20.07	26.18	=25.68*1.0194

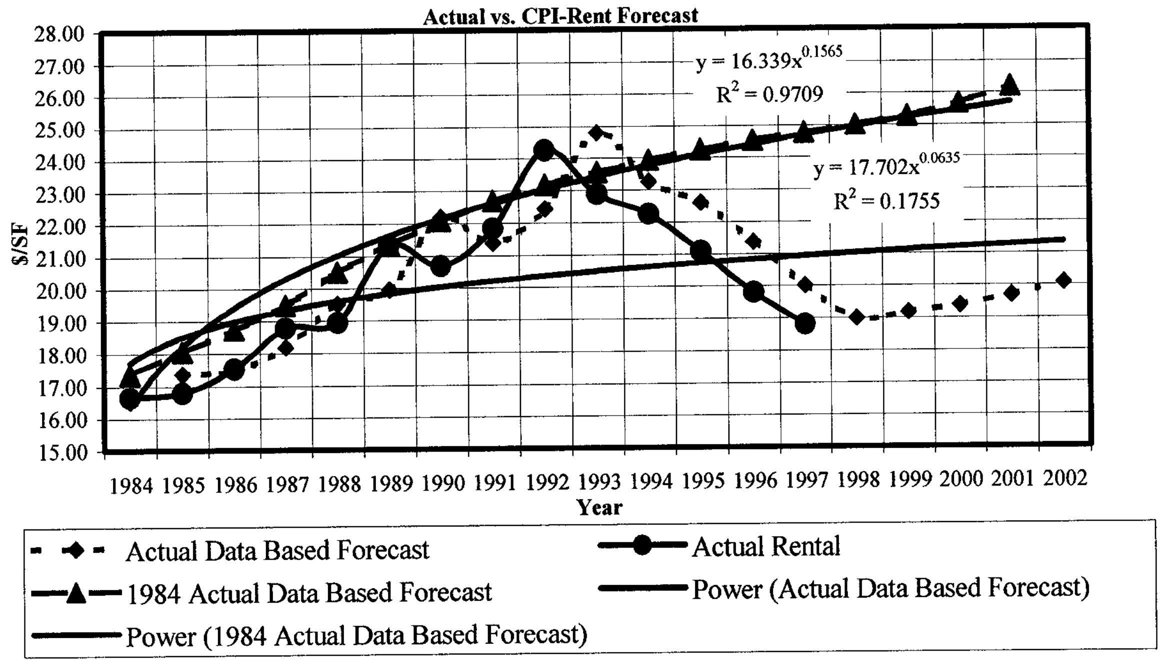

Figure B.27 Actual Rental vs. CPI-Rent Forecasted Rental

B- 3) Forecasting Methods For Retail

Table B-34 Retail Data Comparison

Year	Retail Weighted Average (X_i)	Retail Difference $[X_{(i+1)} - X_{(i)}]$	%Difference $W_i=\left[1-\frac{X_i}{X_{(i+1)}}\right]$	Retail Value ($) Y_i	Retail Difference $(Y_{(i+1)}-Y_i)$	%Difference $V_i=\left[1-\frac{Y_i}{Y_{(i+1)}}\right]$	Average % Difference $Z_i=\frac{2}{3}*W_i+\frac{1}{3}*V_i$
1984	18.25			127,413,320			
1985	18.27	0.02	0.1095%	142,211,755	14,798,435	10.41%	3.54%
1986	18.25	-0.02	-0.1096%	153,785,657	11,573,902	7.53%	2.44%
1987	19.77	1.52	7.6651%	168,893,551	15,107,894	8.95%	8.09%
1988	21.57	1.80	8.3562%	181,652,071	12,758,520	7.02%	7.91%
1989	24.58	3.02	12.2660%	189,301,628	7,649,557	4.04%	9.52%
1990	21.96	-2.62	-11.9320%	192,558,231	3,256,603	1.69%	-7.39%
1991	24.24	2.28	9.3977%	181,614,439	-10,943,792	-6.03%	4.26%
1992	26.26	2.02	7.6888%	185,169,503	3,555,064	1.92%	5.77%
1993	24.31	-1.95	-8.0084%	194,324,749	9,155,246	4.71%	-3.77%
1994	24.12	-0.19	-0.7960%	207,840,624	13,515,875	6.50%	1.64%
1995	23.53	-0.59	-2.5162%	213,773,669	5,933,045	2.78%	-0.75%
1996	22.57	-0.96	-4.2446%	220,869,830	7,096,161	3.21%	-1.76%
1997	15.91	-6.66	-41.8605%	237,836,642	16,966,812	7.13%	-25.53%
R^2 with the Percentage Retail Difference						**-0.19**	**0.99**
1998				246,674,830	8,838,188	3.58%	
1999				260,779,457	14,104,627	5.41%	
2000				277,033,166	16,253,709	5.87%	
2001				289,129,995	12,096,829	4.18%	
2002				306,365,631	17,235,636	5.63%	

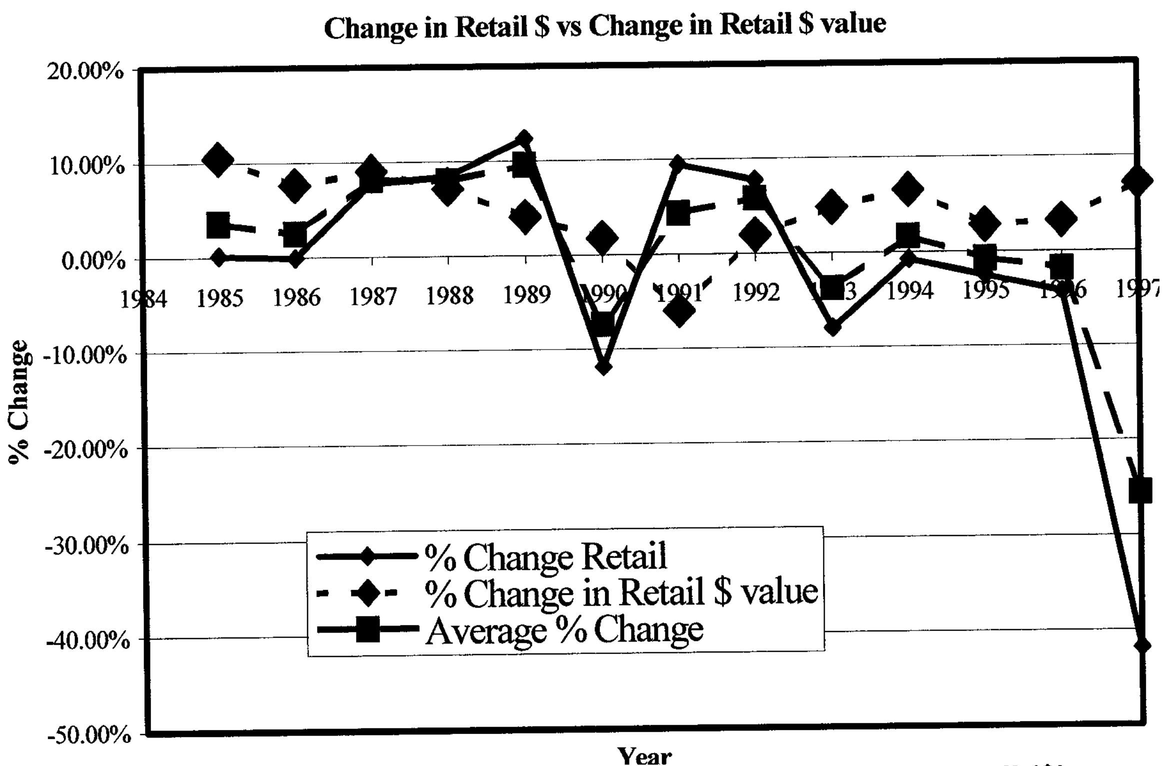

Figure B.28 (%) Change in Retail ($) vs. (%) Change in Retail ($)

Table B-35 Retail Forecast Based on % CPI-Retail ($/SF)

Year	Retail Weighted Average X_i	Average % Difference $(1+Z_i)$	Actual Data Based $D_i = X_{(i-1)}*(1+Z_{(i-1)})$	1984 Based Forecast	
1984	18.25				
1985	18.27	1.0354	18.90	18.90	=18.25*1.0354
1986	18.25	1.0244	18.71	19.36	=1890*1.0244
1987	19.77	1.0809	19.73	20.92	=19.36*1.0809
1988	21.57	1.0791	21.33	22.58	=20.92*1.0791
1989	24.58	1.0952	23.62	24.73	=22.58*1.0952
1990	21.96	0.9261	22.77	22.90	=24.73*0.9261
1991	24.24	1.0426	22.90	23.88	=22.90*1.0426
1992	26.26	1.0577	25.64	25.25	=23.88*1.0577
1993	24.31	0.9623	25.27	24.30	=25.25*0.9623
1994	24.12	1.0164	24.71	24.70	=24.30*1.0164
1995	23.53	0.9925	23.94	24.51	=24.70*0.9925
1996	22.57	0.9824	23.11	24.08	=24.51*0.9824
1997	15.91	0.7447	16.81	17.93	=24.08*0.7447
Coefficient of Correlation (Actual vs. Forecast)			**0.9721**	**0.9775**	

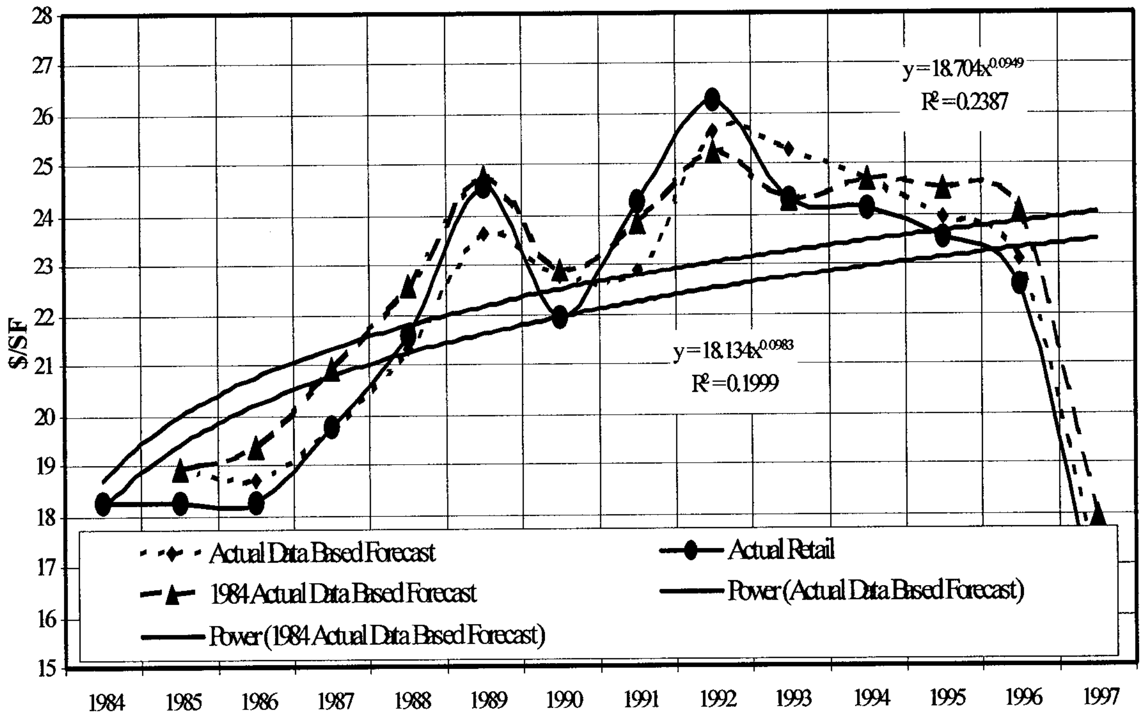

Figure B.29 Actual Retail vs. Forecasted Retail

B- 4) Forecasting Methods For TOEFEL

It is to be noticed that the available data starts from year 1988 and accordingly the data analysis is show in Table B-36 and Figure B.30.

Table B-36 TOEFEL Data Comparison

Year	($/SF) X_i	($/SF) Difference $(X_{(i+1)} - X_i)$	(%) Difference $Y_i = \left[1 - \frac{X_i}{X_{(i+1)}}\right]$	CPI-All Items Z_i	CPI Difference $(Z_{(i+1)} - Z_i)$	(%) Difference $W_i = \left[1 - \frac{Z_i}{Z_{i+1}}\right]$
1988	9.27			84.80		
1989	10.09	0.82	8.13%	89.00	4.2	4.72%
1990	11.44	1.35	11.80%	93.30	4.3	4.61%
1991	11.78	0.34	2.89%	98.50	5.2	5.28%
1992	12.23	0.45	3.68%	100.00	1.5	1.50%
1993	12.67	0.44	3.47%	101.80	1.8	1.77%
1994	12.08	-0.59	-4.88%	102.00	0.2	0.20%
1995	12.06	-0.02	-0.17%	104.20	2.2	2.11%
1996	11.90	-0.16	-1.34%	105.90	1.7	1.61%
1997	11.69	-0.21	-1.80%	107.60	1.7	1.58%
1998				108.60	1	0.92%
1999				110.50	1.9	1.72%
2000				113.50	3	2.64%
2001				116.40	2.9	2.49%
2002				119.00	2.6	2.18%
Coefficient of Correlation with TOEFEL (%) Difference						**0.76**

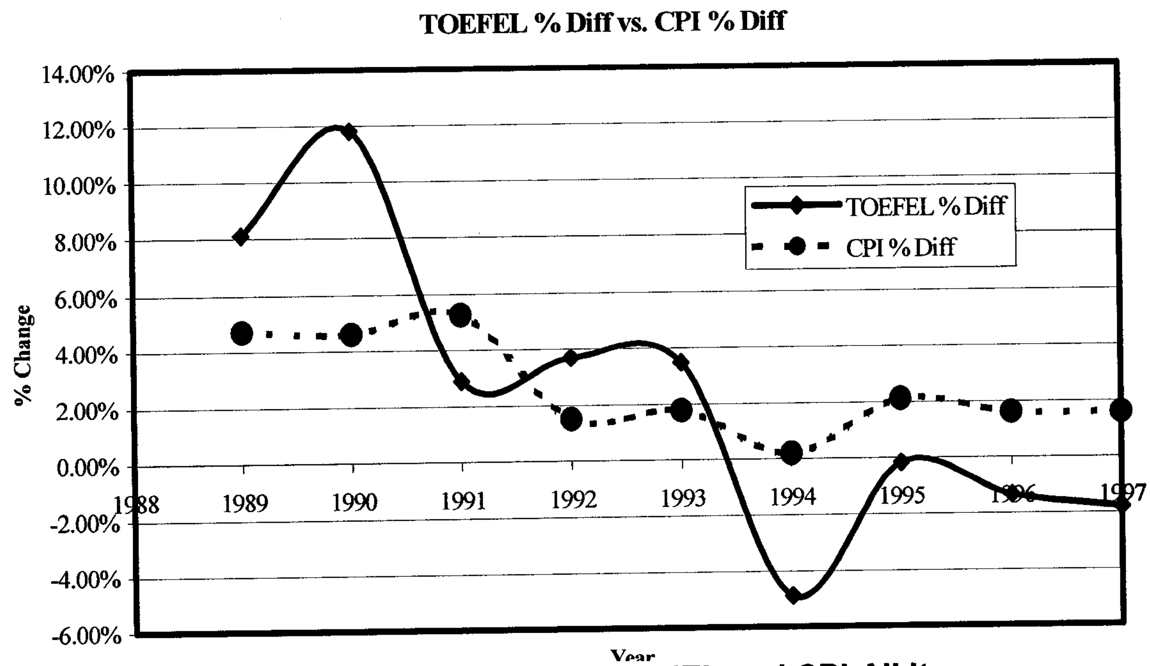

Figure B.30 (%) Change in TOEFEL and CPI-All Items

Table B-37 TOEFEL Forecast Based on % CPI-All Items ($/SF)

Year	Actual TOEFEL X_i	(%) Difference $(1+W_i)$	Actual Data Forecast $D_i = X_{(i-1)}*(1+W_i)$	1984 Based Forecast	
1988	9.27				
1989	10.09	1.0472	9.71	9.71	=09.27*1.0472
1990	11.44	1.0461	10.56	10.15	=09.71*1.0461
1991	11.78	1.0528	12.04	10.69	=10.15*1.0528
1992	12.23	1.0150	11.96	10.85	=10.69*1.0150
1993	12.67	1.0177	12.45	11.04	=10.85*1.0177
1994	12.08	1.0020	12.69	11.06	=11.04*1.0020
1995	12.06	1.0211	12.34	11.30	=11.06*1.0211
1996	11.90	1.0161	12.25	11.48	=11.30*1.0161
1997	11.69	1.0158	12.09	11.66	=11.48*1.0158
Coefficient of Correlation (Actual vs. Forecast)			**0.8868**	**0.7103**	
1998		1.0092		11.77	=11.66*1.0092
1999		1.0172		11.97	=11.77*1.0172
2000		1.0264		12.29	=11.97*1.0264
2001		1.0249		12.59	=12.29*1.0249
2002		1.0218		12.87	=12.59*1.0218

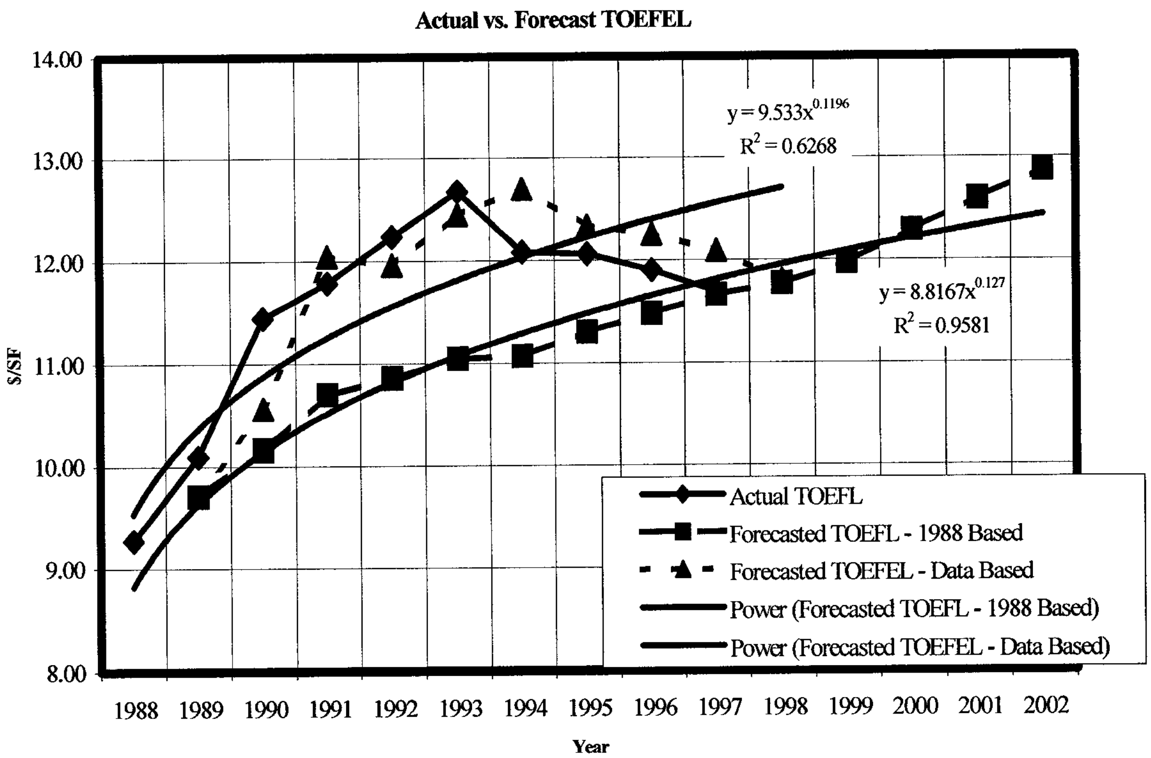

Figure B.31 Actual TOEFEL vs. Forecasted TOEFEL

APPENDIX (C)

LINEAR REGRESSION EQUATIONS

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SAMPLES OF THE TABLES & QUERIES FOR THE PRELIMINARY ESTIMATE

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 196.77x^{-0.1745}$	0.9869	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Installation	$Y = 399.23x^{-0.2334}$	0.9913	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Total Cost	$Y = 572.83x^{-0.2059}$	0.9896	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Perimeter	$Y = 1.2896 X^{0.5715}$	0.9900	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Height Adjustment/1ft	$Y = 125.01 X^{-0.4318}$	0.9724	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Perimeter Adjustment/100ft	$Y = 108349 X^{-1.0025}$	0.9999	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Foundation (1)	$Y = 0.0354e^{-0.000004X}$	0.8545	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm1_1	$Y = 1.2045X^{-0.0347}$	0.7674	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm1_9	$Y = 0.0179X^{0.2106}$	0.7794	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Substructure (2)	$Y = 0.0025 X^{0.1982}$	0.9808	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm2_1	100%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Superstructure (3)	$Y = 0.01 X^{0.2046}$	0.9797	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm3_1	20.72%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm3_5	44.29%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm3_7	29.03%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm3_9	5.81%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Exterior Closure (4)	$Y = 0.1975e^{-0.00001X}$	0.9597	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm4_1	78.97%	0.9618	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm4_5	0.00%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm4_6	1.78%	0.9848	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm4_7	19.23%	0.9598	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Roofing (5)	0.98%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm5_1	$Y =0.3425 X^{0.0927}$	0.9868	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm5_7	0.00%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm5_8	$y = 0.2104e^{-0.00002X}$	0.9241	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.0566\ X^{0.1589}$	0.9864	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm6_1	21.27%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm6_4	$Y = 0.1764\ X^{0.0467}$	0.9806	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm6_5	9.83%	0.9819	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm6_6	$Y = 0.1266\ X^{0.0496}$	0.9854	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm6_7	$Y = 0.0855X^{0.0457}$	0.9846	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm6_9	$Y = 2.9583\ X^{-0.3846}$	0.9816	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Conveying Systems (7)	$Y = 0.0052\ X^{0.1999}$	0.9859	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm7_1	99.91%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Mechanical (8)	$Y = 1.0257\ X^{-0.1274}$	0.9012	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm8_1	$Y = 16.665\ X^{-0.3665}$	0.9959	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm8_2	$Y = 0.0028\ X^{0.3349}$	0.9695	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm8_3	$Y = 0.0075\ X^{0.3337}$	0.9670	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm8_4	$Y =0.0098\ X^{0.3342}$	0.9672	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Electrical (9)	8.16%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm9_1	$Y = 402.18X^{-0.7963}$	0.9974	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm9_2	$Y = 0.1311\ X^{0.1734}$	0.9764	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm9_4	$Y = 0.0135\ X^{0.2072}$	0.9507	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Special Construction (11)	$Y = 0.0032\ X^{0.2000}$	0.9868	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
DivElm11_1	100.40%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists
Area Based on Budget	$Y = 0.0124X - 4558.9$	0.9995	Apartment (13)	Face Brick with Concrete Block Back-up	Wood Joists

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 171.92x^{-0.1594}$	0.9842	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Installation	$Y = 330.92x^{-0.2152}$	0.9894	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Total Cost	$Y = 485.22x^{-0.1888}$	0.9873	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Perimeter	$Y = 1.2896 X^{0.5715}$	0.9900	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Height Adjustment/1ft	$Y = 125.01 X^{-0.4318}$	0.9724	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Perimeter Adjustment/100ft	$Y = 108349 X^{-1.0025}$	0.9999	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Foundation (1)	$Y = 0.0387e^{-0.000006X}$	0.7715	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm1_1	$Y = 0.9084e^{-0.000002X}$	0.8883	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm1_9	$Y =0.0953e^{0.00001X}$	0.8735	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Substructure (2)	$Y = 0.002 X^{0.1995}$	0.9594	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm2_1	100%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Superstructure (3)	$Y = 0.0206 X^{0.1895}$	0.9870	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm3_1	8.56%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm3_5	66.05%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm3_7	14.76%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm3_9	10.66%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Exterior Closure (4)	$Y = 0.1606e^{-0.00001X}$	0.9665	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm4_1	83.33%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm4_5	0.00%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm4_6	$Y = 0.0003X^{0.4215}$	0.9849	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm4_7	14.49%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Roofing (5)	1.79%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm5_1	$Y = -0.0403Ln(X) + 1.083$	0.8313	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm5_7	$Y = 0.088 X^{0.1308}$	0.8972	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm5_8	0.00%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.0514 X^{0.1552}$	0.9841	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm6_1	$Y = 0.1181X^{0.0349}$	0.9886	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm6_4	$Y =0.1907 X^{0.0337}$	0.9675	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm6_5	$Y = 0.0679 X^{0.0384}$	0.9782	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm6_6	$Y =0.1647 X^{0.0363}$	0.9731	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm6_7	$Y = 0.1098 X^{0.0352}$	0.9608	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm6_9	$Y = 3.8383 X^{-0.3976}$	0.9828	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Conveying Systems (7)	$Y = 0.0058 X^{0.188}$	0.9745	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm7_1	100.13%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Mechanical (8)	$Y = 1.2221 X^{-0.145}$	0.9619	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm8_1	$Y = 16.508 X^{-0.3659}$	0.9997	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm8_2	$Y =0.0027 X^{0.3358}$	0.9816	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm8_3	$Y = 0.0074 X^{0.3344}$	0.9802	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm8_4	$Y = 0.0097X^{0.3348}$	0.9804	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Electrical (9)	8.12%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm9_1	$Y = 415.04 X^{-0.7994}$	0.9971	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm9_2	$Y = 0.135 X^{0.1706}$	0.9681	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm9_4	$Y = 0.0138 X^{0.2046}$	0.9427	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Special Construction (11)	$Y = 0.0036 X^{0.1882}$	0.9731	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
DivElm11_1	100.52%	1.0000	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists
Area Based on Budget	$Y = 0.0121X - 4053.6$	0.9997	Apartment (13)	Face Brick with Concrete Block Back-up	Steel Joists

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 161.44x^{-0.1662}$	0.9825	Apartment (13)	Stucco on Concrete Block	Wood Joists
Installation	$Y = 287.6x^{-0.2143}$	0.9871	Apartment (13)	Stucco on Concrete Block	Wood Joists
Total Cost	$Y = 437.03x^{-0.1916}$	0.9852	Apartment (13)	Stucco on Concrete Block	Wood Joists
Perimeter	$Y = 1.2896 X^{0.5715}$	0.9900	Apartment (13)	Stucco on Concrete Block	Wood Joists
Height Adjustment/1ft	$Y = 125.01 X^{-0.4318}$	0.9724	Apartment (13)	Stucco on Concrete Block	Wood Joists
Perimeter Adjustment/100ft	$Y = 108349 X^{-1.0025}$	0.9999	Apartment (13)	Stucco on Concrete Block	Wood Joists
Foundation (1)	$Y = 0.0355e^{-0.000007X}$	0.8985	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm1_1	$Y = 0.8936e^{-0.000004X}$	0.9848	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm1_9	$Y =0.0068X^{0.3258}$	0.9768	Apartment (13)	Stucco on Concrete Block	Wood Joists
Substructure (2)	$Y = 0.0031 X^{0.1895}$	0.9789	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm2_1	100%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
Superstructure (3)	$Y = 0.0098 X^{0.1965}$	0.9766	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm3_1	0.00%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm3_5	56.12%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm3_7	36.79%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm3_9	7.36%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
Exterior Closure (4)	$Y = 0.1158e^{-0.00001X}$	0.9554	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm4_1	0.00%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm4_5	$Y = 0.0.5971e^{-0.0000007X}$	0.9018	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm4_6	$Y = 0.0006 X^{0.4152}$	0.9818	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm4_7	$Y = 0.3843e^{-0.0000007X}$	0.8334	Apartment (13)	Stucco on Concrete Block	Wood Joists
Roofing (5)	1.11%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm5_1	85.88%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm5_7	0.00%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm5_8	$Y = 0.221e^{-0.00002X}$	0.9817	Apartment (13)	Stucco on Concrete Block	Wood Joists

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.0589\ X^{0.1591}$	0.9822	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm6_1	$Y = 0.1472\ X^{0.0329}$	0.9507	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm6_4	$Y = 0.1845X^{0.0326}$	0.9720	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm6_5	$Y = 0.0659\ X^{0.0369}$	0.9828	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm6_6	$Y = 0.1595\ X^{0.0351}$	0.9851	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm6_7	$Y = 0.1074\ X^{0.0315}$	0.9692	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm6_9	$Y = 3.712\ X^{-0.3987}$	0.9819	Apartment (13)	Stucco on Concrete Block	Wood Joists
Conveying Systems (7)	$Y = 0.0061\ X^{0.1966}$	0.9813	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm7_1	100.06%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
Mechanical (8)	$Y = 1.3545\ X^{-0.1422}$	0.9653	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm8_1	$Y = 16.537\ X^{-0.3661}$	0.9996	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm8_2	$Y = 0.0028\ X^{0.3351}$	0.9807	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm8_3	$Y = 0.0074\ X^{0.3342}$	0.9795	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm8_4	$Y =0.0097\ X^{0.3346}$	0.9800	Apartment (13)	Stucco on Concrete Block	Wood Joists
Electrical (9)	9.28%	0.9868	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm9_1	$Y = 408.58\ X^{-0.7979}$	0.9974	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm9_2	$Y =0.1335\ X^{0.1715}$	0.9773	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm9_4	$Y = 0.0137\ X^{0.2055}$	0.9494	Apartment (13)	Stucco on Concrete Block	Wood Joists
Special Construction (11)	$Y = 0.0041\ X^{0.1878}$	0.9744	Apartment (13)	Stucco on Concrete Block	Wood Joists
DivElm11_1	99.77%	1.0000	Apartment (13)	Stucco on Concrete Block	Wood Joists
Area Based on Budget	$Y = 0.0138X -4092.8$	0.9998	Apartment (13)	Stucco on Concrete Block	Wood Joists

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 157.94x^{-0.1556}$	0.9826	Apartment (13)	Stucco on Concrete Block	Steel Joists
Installation	$Y = 277.73x^{-0.2059}$	0.9871	Apartment (13)	Stucco on Concrete Block	Steel Joists
Total Cost	$Y = 423.07x^{-0.1817}$	0.9864	Apartment (13)	Stucco on Concrete Block	Steel Joists
Perimeter	$Y = 1.2896\ X^{0.5715}$	0.9900	Apartment (13)	Stucco on Concrete Block	Steel Joists
Height Adjustment/1ft	$Y = 125.01\ X^{-0.4318}$	0.9724	Apartment (13)	Stucco on Concrete Block	Steel Joists
Perimeter Adjustment/100ft	$Y = 108349\ X^{-1.0025}$	0.9999	Apartment (13)	Stucco on Concrete Block	Steel Joists
Foundation (1)	$Y = 0.039e^{-0.000005X}$	0.9041	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm1_1	$Y = 0.8967e^{-0.000002X}$	0.9359	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm1_9	$Y =0.0092X^{0.2737}$	0.9839	Apartment (13)	Stucco on Concrete Block	Steel Joists
Substructure (2)	$Y = 0.0029\ X^{0.1905}$	0.9751	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm2_1	100%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
Superstructure (3)	$Y = 0.0199\ X^{0.1796}$	0.9810	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm3_1	5.74%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm3_5	68.04%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm3_7	13.59%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm3_9	12.62%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
Exterior Closure (4)	$Y = 0.1098e^{-0.00001X}$	0.9538	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm4_1	0.00%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm4_5	58.65%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm4_6	$Y = 0.0006X^{0.4152}$	0.9806	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm4_7	$Y = 0.8373e^{-0.0000008X}$	0.8373	Apartment (13)	Stucco on Concrete Block	Steel Joists
Roofing (5)	1.31%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm5_1	$Y = 4.1034\ X^{-0.2348}$	0.9669	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm5_7	$Y = 0.067\ X^{0.1964}$	0.9775	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm5_8	$Y = 0.1561e^{-0.00001X}$	0.9754	Apartment (13)	Stucco on Concrete Block	Steel Joists

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.0612\ X^{0.1486}$	0.9805	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm6_1	$Y = 0.1463\ X^{0.0336}$	0.9519	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm6_4	$Y = 0.1832\ X^{0.0333}$	0.9800	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm6_5	$Y = 0.0041\ X^{0.1852}$	0.9884	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm6_6	$Y = 0.0652\ X^{0.0381}$	0.9747	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm6_7	$Y = 0.1069\ X^{0.0319}$	0.9689	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm6_9	$Y = 3.6927\ X^{-0.3981}$	0.9819	Apartment (13)	Stucco on Concrete Block	Steel Joists
Conveying Systems (7)	$Y = 0.0064\ X^{0.185}$	0.9802	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm7_1	100.47%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
Mechanical (8)	$Y = 1.3931\ X^{-0.1516}$	0.9696	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm8_1	$Y = 16.616\ X^{-0.3666}$	0.9997	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm8_2	$Y = 0.0028\ X^{0.3335}$	0.9814	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm8_3	$Y = 0.0075\ X^{0.3337}$	0.9799	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm8_4	$Y =0.0098\ X^{0.3342}$	0.9804	Apartment (13)	Stucco on Concrete Block	Steel Joists
Electrical (9)	8.68%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm9_1	$Y = 413.79\ X^{-0.799}$	0.9972	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm9_2	$Y = 0.1349\ X^{0.1707}$	0.9717	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm9_4	$Y = 0.0138\ X^{0.2048}$	0.9445	Apartment (13)	Stucco on Concrete Block	Steel Joists
Special Construction (11)	$Y = 0.0046\ X^{0.1702}$	0.9737	Apartment (13)	Stucco on Concrete Block	Steel Joists
DivElm11_1	99.23%	1.0000	Apartment (13)	Stucco on Concrete Block	Steel Joists
Area Based on Budget	$Y = 0.0128X - 3832$	0.9998	Apartment (13)	Stucco on Concrete Block	Steel Joists

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 180.64x^{-0.1745}$	0.9851	Apartment (13)	Wood Siding	Wood Frame
Installation	$Y = 267.55x^{-0.2094}$	0.9853	Apartment (13)	Wood Siding	Wood Frame
Total Cost	$Y = 441.88x^{-0.1924}$	0.9852	Apartment (13)	Wood Siding	Wood Frame
Perimeter	$Y = 1.2896\ X^{0.5715}$	0.9900	Apartment (13)	Wood Siding	Wood Frame
Height Adjustment/1ft	$Y = 125.01\ X^{-0.4318}$	0.9724	Apartment (13)	Wood Siding	Wood Frame
Perimeter Adjustment/100ft	$Y = 108349\ X^{-1.0025}$	0.9999	Apartment (13)	Wood Siding	Wood Frame
Foundation (1)	$Y = 0.0359e^{-0.000008X}$	0.9305	Apartment (13)	Wood Siding	Wood Frame
DivElm1_1	$Y = 0.87986e^{-0.000003X}$	0.9096	Apartment (13)	Wood Siding	Wood Frame
DivElm1_9	$Y = 0.0061X^{0.3375}$	0.9797	Apartment (13)	Wood Siding	Wood Frame
Substructure (2)	$Y = 0.0031\ X^{0.1895}$	0.9789	Apartment (13)	Wood Siding	Wood Frame
DivElm2_1	100%	1.0000	Apartment (13)	Wood Siding	Wood Frame
Superstructure (3)	$Y = 0.01\ X^{0.194}$	0.9803	Apartment (13)	Wood Siding	Wood Frame
DivElm3_1	0.00%	1.0000	Apartment (13)	Wood Siding	Wood Frame
DivElm3_5	56.13%	1.0000	Apartment (13)	Wood Siding	Wood Frame
DivElm3_7	36.79%	1.0000	Apartment (13)	Wood Siding	Wood Frame
DivElm3_9	7.36%	1.0000	Apartment (13)	Wood Siding	Wood Frame
Exterior Closure (4)	$Y = 0.119e^{-0.00001X}$	0.9637	Apartment (13)	Wood Siding	Wood Frame
DivElm4_1	$Y = 0.702X^{-0.0158}$	0.8564	Apartment (13)	Wood Siding	Wood Frame
DivElm4_5	0.00%	1.0000	Apartment (13)	Wood Siding	Wood Frame
DivElm4_6	$Y = 0.0006\ X^{0.4129}$	0.9827	Apartment (13)	Wood Siding	Wood Frame
DivElm4_7	36.60%	1.0000	Apartment (13)	Wood Siding	Wood Frame
Roofing (5)	1.11%	1.0000	Apartment (13)	Wood Siding	Wood Frame
DivElm5_1	85.64%	1.0000	Apartment (13)	Wood Siding	Wood Frame
DivElm5_7	0.00%	1.0000	Apartment (13)	Wood Siding	Wood Frame
DivElm5_8	$Y = 0.2193e^{-0.00002X}$	0.9815	Apartment (13)	Wood Siding	Wood Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.0587 X^{0.1591}$	0.9808	Apartment (13)	Wood Siding	Wood Frame
DivElm6_1	$Y = 0.1461 X^{0.0337}$	0.9392	Apartment (13)	Wood Siding	Wood Frame
DivElm6_4	$Y = 0.1833 X^{0.0333}$	0.9744	Apartment (13)	Wood Siding	Wood Frame
DivElm6_5	$Y =0.0654 X^{0.0377}$	0.9771	Apartment (13)	Wood Siding	Wood Frame
DivElm6_6	$Y = 0.1586 X^{0.0356}$	0.9703	Apartment (13)	Wood Siding	Wood Frame
DivElm6_7	$Y = 0.1068 X^{0.0321}$	0.9629	Apartment (13)	Wood Siding	Wood Frame
DivElm6_9	$Y = 3.7208 X^{-0.3989}$	0.9826	Apartment (13)	Wood Siding	Wood Frame
Conveying Systems (7)	$Y = 0.0064 X^{0.1915}$	0.9759	Apartment (13)	Wood Siding	Wood Frame
DivElm7_1	100.01%	1.0000	Apartment (13)	Wood Siding	Wood Frame
Mechanical (8)	$Y = 1.3391 X^{-0.1413}$	0.9637	Apartment (13)	Wood Siding	Wood Frame
DivElm8_1	$Y = 16.551 X^{-0.3662}$	0.9996	Apartment (13)	Wood Siding	Wood Frame
DivElm8_2	$Y = 0.0028 X^{0.3356}$	0.9804	Apartment (13)	Wood Siding	Wood Frame
DivElm8_3	$Y = 0.0074 X^{0.3343}$	0.9788	Apartment (13)	Wood Siding	Wood Frame
DivElm8_4	$Y = 0.0097 X^{0.3343}$	0.9791	Apartment (13)	Wood Siding	Wood Frame
Electrical (9)	9.20%	1.0000	Apartment (13)	Wood Siding	Wood Frame
DivElm9_1	$Y = 422.63 X^{-0.801}$	0.9979	Apartment (13)	Wood Siding	Wood Frame
DivElm9_2	$Y = 0.1374 X^{0.1689}$	0.9813	Apartment (13)	Wood Siding	Wood Frame
DivElm9_4	$Y = 0.0141 X^{0.2029}$	0.9555	Apartment (13)	Wood Siding	Wood Frame
Special Construction (11)	$Y = 0.0041 X^{0.1888}$	0.9887	Apartment (13)	Wood Siding	Wood Frame
DivElm11_1	99.90%	1.0000	Apartment (13)	Wood Siding	Wood Frame
Area Based on Budget	$Y = 0.0138X - 4115.3$	0.9998	Apartment (13)	Wood Siding	Wood Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 193.38x^{-0.1795}$	0.9867	Apartment (13)	Brick Veneer	Wood Frame
Installation	$Y = 350.42x^{-0.2282}$	0.9894	Apartment (13)	Brick Veneer	Wood Frame
Total Cost	$Y = 528.7x^{-0.2052}$	0.9882	Apartment (13)	Brick Veneer	Wood Frame
Perimeter	$Y = 1.2896\ X^{0.5715}$	0.9900	Apartment (13)	Brick Veneer	Wood Frame
Height Adjustment/1ft	$Y = 125.01\ X^{-0.4318}$	0.9724	Apartment (13)	Brick Veneer	Wood Frame
Perimeter Adjustment/100ft	$Y = 108349\ X^{-1.0025}$	0.9999	Apartment (13)	Brick Veneer	Wood Frame
Foundation (1)	$Y = 0.0331e^{-0.000007X}$	0.9005	Apartment (13)	Brick Veneer	Wood Frame
DivElm1_1	$Y = 0.8917e^{-0.000003X}$	0.8582	Apartment (13)	Brick Veneer	Wood Frame
DivElm1_9	$Y = 0.0064X^{0.3325}$	0.9789	Apartment (13)	Brick Veneer	Wood Frame
Substructure (2)	$Y = 0.0026\ X^{0.1998}$	0.9789	Apartment (13)	Brick Veneer	Wood Frame
DivElm2_1	100%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
Superstructure (3)	$Y = 0.0086\ X^{0.2035}$	0.9899	Apartment (13)	Brick Veneer	Wood Frame
DivElm3_1	0.00%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
DivElm3_5	56.03%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
DivElm3_7	36.72%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
DivElm3_9	7.35%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
Exterior Closure (4)	$Y = 0.1795e^{-0.00001X}$	0.9622	Apartment (13)	Brick Veneer	Wood Frame
DivElm4_1	$Y = 0.8252X^{-0.0095}$	0.9288	Apartment (13)	Brick Veneer	Wood Frame
DivElm4_5	0.00%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
DivElm4_6	$Y = 0.0003\ X^{0.4212}$	0.9832	Apartment (13)	Brick Veneer	Wood Frame
DivElm4_7	22.83%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
Roofing (5)	0.88%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
DivElm5_1	80.51%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
DivElm5_7	0.00%	1.0000	Apartment (13)	Brick Veneer	Wood Frame
DivElm5_8	$Y = 0.255e^{-0.00002X}$	0.9203	Apartment (13)	Brick Veneer	Wood Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 160.15x^{-0.1094}$	0.9884	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Installation	$Y = 117.02x^{-0.095}$	0.9920	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Total Cost	$Y = 276.32x^{-0.1028}$	0.9906	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Perimeter	Y = 226.05Ln(X)-2243.1	0.9648	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Height Adjustment/1ft	Y = -4E-06x + 1.9318	0.9557	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Perimeter Adjustment/100ft	$Y = 548138\ X^{-1.0169}$	0.9989	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Foundation (1)	1%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm1_1	Y = -3E-07x + 0.9872	0.7963	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm1_9	$Y = 0.0218x^{0.1026}$	0.9898	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Substructure (2)	0.30%	0.9808	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm2_1	100%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Superstructure (3)	$Y = 0.0466x^{0.1034}$	0.9849	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm3_1	20.60%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm3_5	69.49%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm3_7	1.93%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm3_9	7.98%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Exterior Closure (4)	Y = -2E-07x + 0.145	0.9629	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm4_1	Y = -3E-07x + 0.792	0.9823	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm4_5	0.00%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm4_6	Y = 4E-07x + 0.075	0.9665	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm4_7	Y = -6E-08x + 0.1381	0.9685	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Roofing (5)	0.30%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm5_1	65.00%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm5_7	36.00%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm5_8	0.00%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.1459x^{0.0599}$	0.9911	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm6_1	$Y = 0.4001x^{-0.0133}$	0.9456	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm6_4	Y = 6E-08x + 0.226	0.9696	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm6_5	8.97%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm6_6	Y = 5E-08x + 0.1668	0.9632	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm6_7	Y = 3E-08x + 0.1085	0.9704	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm6_9	Y = -1E-07x + 0.0644	0.9754	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Conveying Systems (7)	$Y = 0.0201x^{0.104}$	0.9714	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm7_1	100.19%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Mechanical (8)	24%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm8_1	$Y = 1.5199x^{-0.107}$	0.9937	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm8_2	$Y = 1.0296x^{-0.1902}$	0.9962	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm8_3	$Y = 0.0353x^{0.1442}$	0.9854	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm8_4	$Y = 0.0486x^{0.1439}$	0.9861	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Electrical (9)	8.23%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm9_1	$Y = 4178.2x^{-0.9172}$	0.9994	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm9_2	$Y = 0.2968x^{0.073}$	0.9850	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm9_4	$Y = 0.0748x^{0.0876}$	0.9851	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Special Construction (11)	Y = 2E-08x + 0.0213	0.9143	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
DivElm11_1	99.17%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame
Area Based on Budget	y = 0.0104x - 17924	0.9997	Apartment (824)	Ribbed Precast Concrete Panel	Steel Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 162.24x^{-0.1244}$	0.9892	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Installation	$Y = 106.6x^{-0.0822}$	0.9933	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Total Cost	$Y = 260.71x^{-0.1025}$	0.9920	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Perimeter	Y = 226.05Ln(X)-2243.1	0.9648	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Height Adjustment/1ft	$Y = 125.01 X^{-0.4318}$	0.9724	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Perimeter Adjustment/100ft	$Y = 548138 X^{-1.0169}$	0.9989	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Foundation (1)	1.02%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm1_1	93.16%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm1_9	Y = 0.0153Ln(x) - 0.1065	0.8563	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Substructure (2)	0.37%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm2_1	100%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Superstructure (3)	$Y = 0.0495x^{0.1019}$	0.9893	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm3_1	13.64%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm3_5	77.87%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm3_7	5.45%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm3_9	3.01%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Exterior Closure (4)	Y = -2E-07x + 0.1429	0.9686	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm4_1	76.41%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm4_5	0.00%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm4_6	Y = 4E-08x + 0.0057	0.9655	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm4_7	22.30%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Roofing (5)	0.39%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm5_1	60.00%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm5_7	32.00%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm5_8	8.00%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.1059x^{0.0793}$	0.9942	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm6_1	$Y = 4E-08x + 0.2862$	0.9656	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm6_4	$Y = 3E-08x + 0.2222$	0.9669	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm6_5	$Y = 0.0702x^{0.0258}$	0.9503	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm6_6	$Y = 3E-08x + 0.1966$	0.9512	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm6_7	$Y = 2E-08x + 0.1279$	0.9649	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm6_9	$Y = -2E-07x + 0.0754$	0.9750	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Conveying Systems (7)	$Y = 0.0227x^{0.0984}$	0.9714	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm7_1	100.10%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Mechanical (8)	25.33%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm8_1	$Y = 1.5247x^{-0.1072}$	0.9945	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm8_2	$Y = 1.0434x^{-0.1913}$	0.9962	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm8_3	$Y = 0.0354x^{0.1439}$	0.9835	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm8_4	$Y = 0.0489x^{0.1436}$	0.9838	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Electrical (9)	8.12%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm9_1	$Y = 4306.7x^{-0.9198}$	0.9994	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm9_2	$Y = 0.3056x^{0.0704}$	0.9462	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm9_4	$Y = 0.0773x^{0.0848}$	0.9571	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Special Construction (11)	$Y = 0.0083x^{0.0928}$	0.8935	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
DivElm11_1	100.12%	1.0000	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame
Area Based on Budget	$Y = 0.011x - 17861$	0.9997	Apartment (824)	Ribbed Precast Concrete Panel	R/C Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 106.68x^{-0.0898}$	0.9933	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Installation	$Y = 191.54x^{-0.1322}$	0.9886	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Total Cost	$Y = 288.77x^{-0.1117}$	0.9908	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Perimeter	$Y = 226.05Ln(x) - 2243.1$	0.9648	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Height Adjustment/1ft	$Y = 125.01 X^{-0.4318}$	0.9724	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Perimeter Adjustment/100ft	$Y = 548138 X^{-1.0169}$	0.9989	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Foundation (1)	1.34%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm1_1	93.53%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm1_9	$Y = 0.0044x^{0.2175}$	0.9399	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Substructure (2)	0.37%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm2_1	100%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Superstructure (3)	$Y =0.0372x^{0.1121}$	0.9910	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm3_1	5.01%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm3_5	83.65%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm3_7	1.48%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm3_9	9.83%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Exterior Closure (4)	$Y = -3E-07x + 0.1646$	0.9672	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm4_1	79.55%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm4_5	0.00%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm4_6	$Y = 3E-08x + 0.005$	0.9687	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm4_7	19.43%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Roofing (5)	0.38%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm5_1	60.00%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm5_7	32.00%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm5_8	7.00%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.097x^{0.0873}$	0.9927	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm6_1	$Y = 0.2194x^{0.0243}$	0.9441	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm6_4	$Y = 0.1715x^{0.0236}$	0.9316	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm6_5	$Y = 0.069x^{0.0273}$	0.9639	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm6_6	$Y = 0.1487x^{0.0255}$	0.9201	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm6_7	$Y = 0.0977x^{0.0246}$	0.9407	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm6_9	$Y = -2E-07x + 0.0753$	0.9753	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Conveying Systems (7)	$Y = 0.0201x^{0.1092}$	0.9791	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm7_1	100.09%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Mechanical (8)	25.60%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm8_1	$Y = 1.5242x^{-0.1072}$	0.9911	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm8_2	$Y = 1.0424x^{-0.1913}$	0.9948	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm8_3	$Y = 0.0355x^{0.1437}$	0.9869	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm8_4	$Y = 0.0487x^{0.1439}$	0.9867	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Electrical (9)	8.77%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm9_1	$Y = 4425.7x^{-0.9219}$	0.9994	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm9_2	$Y = 0.3124x^{0.0688}$	0.9480	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm9_4	$Y = 0.0788x^{0.0834}$	0.9553	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Special Construction (11)	2.55%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
DivElm11_1	99.76%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame
Area Based on Budget	$Y = 0.0113x - 19736$	0.9996	Apartment (824)	Face Brick with Concrete Block Back-up	Steel Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 106.28x^{-0.0954}$	0.9934	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Installation	$Y = 180.68x^{-0.1186}$	0.9885	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Total Cost	$Y = 284.17x^{-0.1084}$	0.9907	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Perimeter	$Y = 226.05Ln(x) - 2243.1$	0.9648	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Height Adjustment/1ft	$Y = 125.01 X^{-0.4318}$	0.9724	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Perimeter Adjustment/100ft	$Y = 548138 X^{-1.0169}$	0.9989	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Foundation (1)	1%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm1_1	$Y = -4E-07x + 1.0066$	0.9117	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm1_9	$Y = 0.021x^{0.1088}$	0.9907	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Substructure (2)	0.34%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm2_1	100%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Superstructure (3)	$Y = 0.0432x^{0.1121}$	0.9933	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm3_1	13.65%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm3_5	77.90%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm3_7	5.45%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm3_9	3.02%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Exterior Closure (4)	$Y = -3E-07x + 0.1611$	0.9688	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm4_1	60.11%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm4_5	0.00%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm4_6	$Y = 3E-08x + 0.005$	0.9705	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm4_7	19.42%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Roofing (5)	0.32%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm5_1	65.00%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm5_7	30.00%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm5_8	6%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.1035x^{0.0799}$	0.9897	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm6_1	$Y = 0.2086x^{0.0285}$	0.9696	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm6_4	Y = 4E-08x + 0.221	0.9702	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm6_5	$Y = 0.0659x^{0.0311}$	0.9769	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm6_6	Y = 4E-08x + 0.1957	0.9686	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm6_7	Y = 2E-08x + 0.1272	0.9817	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm6_9	Y = -1E-07x + 0.0752	0.9736	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Conveying Systems (7)	$Y = 0.0198x^{0.1086}$	0.9795	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm7_1	99.98%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Mechanical (8)	24.94%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm8_1	$Y = 1.5484x^{-1085}$	0.9920	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm8_2	$Y = 1.0588x^{-0.1925}$	0.9953	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm8_3	$Y = 0.036x^{0.1425}$	0.9860	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm8_4	$Y = 0.0495x^{0.1426}$	0.9868	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Electrical (9)	8.60%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm9_1	$Y = 4585.7x^{-0.9249}$	0.9994	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm9_2	$Y = 0.3278x^{0.0647}$	0.9379	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm9_4	$Y = 0.0826x^{0.0794}$	0.9484	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Special Construction (11)	Y = 0.0032Ln(x) - 0.0136	0.9419	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
DivElm11_1	99.56%	1.0000	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame
Area Based on Budget	Y = 0.0109x - 19062	0.9996	Apartment (824)	Face Brick with Concrete Block Back-up	R/C Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 83.401x^{-0.0727}$	0.9945	Apartment (824)	Stucco on Concrete Block	Steel Frame
Installation	$Y = 125.39x^{-0.1033}$	0.9921	Apartment (824)	Stucco on Concrete Block	Steel Frame
Total Cost	$Y = 204.77x^{-0.0881}$	0.9932	Apartment (824)	Stucco on Concrete Block	Steel Frame
Perimeter	Y = 226.05Ln(x) - 2243.1	0.9648	Apartment (824)	Stucco on Concrete Block	Steel Frame
Height Adjustment/1ft	$Y = 125.01 X^{-0.4318}$	0.9724	Apartment (824)	Stucco on Concrete Block	Steel Frame
Perimeter Adjustment/100ft	$Y = 548138 X^{-1.0169}$	0.9989	Apartment (824)	Stucco on Concrete Block	Steel Frame
Foundation (1)	1.43%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm1_1	93.15%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm1_9	Y = 0.0104Ln(x) - 0.0653	0.9131	Apartment (824)	Stucco on Concrete Block	Steel Frame
Substructure (2)	0.40%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm2_1	100%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
Superstructure (3)	$Y = 0.0522x^{0.0886}$	0.9850	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm3_1	5.02%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm3_5	83.78%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm3_7	1.49%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm3_9	9.85%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
Exterior Closure (4)	Y = -2E-07x + 0.0892	0.9639	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm4_1	0.00%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm4_5	59.66%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm4_6	Y = 6E-08x + 0.01	0.9632	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm4_7	38.46%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
Roofing (5)	0.40%		Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm5_1	59.00%		Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm5_7	32.00%		Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm5_8	6.00%		Apartment (824)	Stucco on Concrete Block	Steel Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.1408x^{0.0612}$	0.9900	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm6_1	29.30%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm6_4	22.72%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm6_5	9.55%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm6_6	20.15%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm6_7	13.09%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm6_9	$Y = -2E-07x + 0.0752$	0.9789	Apartment (824)	Stucco on Concrete Block	Steel Frame
Conveying Systems (7)	$Y = 0.0279x^{0.087}$	0.9722	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm7_1	99.84%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
Mechanical (8)	$Y = 0.5172x^{-0.0538}$	0.9411	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm8_1	$Y = 1.5955x^{-0.1112}$	0.9628	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm8_2	$Y = 1.0818x^{-0.1945}$	0.9841	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm8_3	$Y = 0.0372x^{0.1396}$	0.9818	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm8_4	$Y = 0.051x^{0.1398}$	0.9819	Apartment (824)	Stucco on Concrete Block	Steel Frame
Electrical (9)	9.30%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm9_1	$Y = 4290.3x^{-0.9194}$	0.9986	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm9_2	$Y = 0.3024x^{0.0715}$	0.9330	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm9_4	$Y = 0.0763x^{0.086}$	0.9504	Apartment (824)	Stucco on Concrete Block	Steel Frame
Special Construction (11)	$Y = 0.0097x^{0.0859}$	0.8935	Apartment (824)	Stucco on Concrete Block	Steel Frame
DivElm11_1	99.18%	1.0000	Apartment (824)	Stucco on Concrete Block	Steel Frame
Area Based on Budget	$Y = 0.0116x - 15014$	0.9999	Apartment (824)	Stucco on Concrete Block	Steel Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Material	$Y = 81.697 X^{-0.0772}$	0.9947	Apartment (824)	Stucco on Concrete Block	R/C Frame
Installation	$Y = 121.95x^{-0.0916}$	0.9919	Apartment (824)	Stucco on Concrete Block	R/C Frame
Total Cost	$Y = 203.07x^{-0.0853}$	0.9933	Apartment (824)	Stucco on Concrete Block	R/C Frame
Perimeter	Y = 226.05Ln(x) - 2243.1	0.9648	Apartment (824)	Stucco on Concrete Block	R/C Frame
Height Adjustment/1ft	$Y = 125.01 X^{-0.4318}$	0.9724	Apartment (824)	Stucco on Concrete Block	R/C Frame
Perimeter Adjustment/100ft	$Y = 548138 X^{-1.0169}$	0.9989	Apartment (824)	Stucco on Concrete Block	R/C Frame
Foundation (1)	1.08%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm1_1	92.67%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm1_9	Y = 9E-08x + 0.0617	0.8051	Apartment (824)	Stucco on Concrete Block	R/C Frame
Substructure (2)	0.40%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm2_1	100%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
Superstructure (3)	$Y = 0.0626x^{0.086}$	0.9886	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm3_1	13.65%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm3_5	77.93%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm3_7	5.45%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm3_9	3.02%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
Exterior Closure (4)	Y = -2E-07x + 0.0879	0.9676	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm4_1	0.00%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm4_5	59.68%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm4_6	Y = 6E-08x + 0.0098	0.9647	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm4_7	38.48%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
Roofing (5)	0.40%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm5_1	60.00%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm5_7	31.00%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm5_8	6%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame

Parameter	Equation	R^2	Project Type	Exterior Wall Type	Framing Type
Interior Construction (6)	$Y = 0.1401x^{0.0595}$	0.9846	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm6_1	Y = 5E-08x + 0.2856	0.9757	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm6_4	Y = 4E-08x + 0.2216	0.9603	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm6_5	$Y = 0.068x^{0.0285}$	0.9727	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm6_6	Y = 3E-08x + 0.1962	0.9576	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm6_7	Y = 2E-08x + 0.1276	0.9732	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm6_9	Y = -1E-07x + 0.0752	0.9730	Apartment (824)	Stucco on Concrete Block	R/C Frame
Conveying Systems (7)	$Y = 0.0294x^{0.0806}$	0.9889	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm7_1	99.89%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
Mechanical (8)	$Y = 0.5289x^{-0.0578}$	0.9502	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm8_1	$Y = 1.5403x^{-0.1081}$	0.9879	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm8_2	$Y = 1.0535x^{-0.1922}$	0.9933	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm8_3	$Y = 0.0358x^{0.1429}$	0.9915	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm8_4	$Y = 0.0493x^{0.1428}$	0.9907	Apartment (824)	Stucco on Concrete Block	R/C Frame
Electrical (9)	9.10%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm9_1	$Y = 4223.7x^{-0.9181}$	0.9995	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm9_2	$Y = 0.2988x^{0.0724}$	0.9822	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm9_4	$Y = 0.0753x^{0.0871}$	0.9889	Apartment (824)	Stucco on Concrete Block	R/C Frame
Special Construction (11)	$Y = 0.009x^{0.0892}$	0.8935	Apartment (824)	Stucco on Concrete Block	R/C Frame
DivElm11_1	100.58%	1.0000	Apartment (824)	Stucco on Concrete Block	R/C Frame
Area Based on Budget	Y = 0.0113x - 14462	0.9999	Apartment (824)	Stucco on Concrete Block	R/C Frame

SAMPLE TABLE BY DIVISION OF THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE

SNumber	Description	Unit	Quantity	Material	Installation	Total
0111207010	Spread Footings		1	$0.00	$0.00	$0.00
0111207090	Spread Footings, 3000 PSI concrete, chute delivered	EACH	1	$0.00	$0.00	$0.00
0111207100	Spread Footings,3000 PSI conc, load 25K, soil cap 3 KSF, 3'-0" sq x 12" d	EACH	1	$39.50	$77.50	$117.00
0111207150	Spread Footings,3000 PSI conc, load 50K, soil cap 3 KSF, 4'-6" sq x 12" d	EACH	1	$81.50	$135.00	$216.50
0111207200	Spread Footings,3000 PSI conc, load 50K, soil cap 6 KSF, 3'-0" sq x 12" d	EACH	15	$39.50	$77.50	$117.00
0111207250	Spread Footings,3000 PSI conc, load 75K, soil cap 3 KSF, 5'-6" sq x 13" d	EACH	1	$127.00	$191.00	$318.00
0111207300	Spread Footings,3000 PSI conc, load 75K, soil cap 6 KSF, 4'-0" sq x 12" d	EACH	1	$66.50	$115.00	$181.50
0111207350	Spread Footings,3000 PSI conc, ld 100K, soil cap 3 KSF, 6'-0" sq x 14" d	EACH	1	$160.00	$229.00	$389.00
0111207410	Spread Footings,3000 PSI conc, ld 100K, soil cap 6 KSF, 4'-6" sq x 15" d	EACH	1	$99.50	$159.00	$258.50
0111207450	Spread Footings,3000 PSI conc, ld 125K, soil cap 3 KSF, 7'-0" sq x 17" d	EACH	1	$252.00	$330.00	$582.00
0111207500	Spread Footings,3000 PSI conc, ld 125K, soil cap 6 KSF, 5'-0" sq x 16" d	EACH	1	$127.00	$191.00	$318.00
0111207550	Spread Footings,3000 PSI conc, ld 150K, soil cap 3 KSF, 7'-6" sq x 18" d	EACH	1	$305.00	$385.00	$690.00
0111207610	Spread Footings,3000 PSI conc, ld 150K, soil cap 6 KSF, 5'-6" sq x 18" d	EACH	1	$168.00	$240.00	$408.00
0111207650	Spread Footings,3000 PSI conc, ld 200K, soil cap 3 KSF, 8'-6" sq x 20" d	EACH	1	$430.00	$505.00	$935.00
0111207700	Spread Footings,3000 PSI conc, ld 200K, soil cap 6 KSF, 6'-0" sq x 20" d	EACH	1	$219.00	$295.00	$514.00
0111207750	Spread Footings,3000 PSI conc, ld 300K, soil cap 3 KSF, 10'-6" sq x 25" d	EACH	1	$780.00	$825.00	$1,605.00
0111207810	Spread Footings,3000 PSI conc, ld 300K, soil cap 6 KSF, 7'-6" sq x 25" d	EACH	1	$410.00	$500.00	$910.00
0111207850	Spread Footings,3000 PSI conc, ld 400K, soil cap 3 KSF, 12'-6" sq x 28" d	EACH	1	$1,225.00	$1,225.00	$2,450.00
0111207900	Spread Footings,3000 PSI conc, ld 400K, soil cap 6 KSF, 8'-6" sq x 27" d	EACH	1	$570.00	$645.00	$1,215.00
0111207950	Spread Footings,3000 PSI conc, ld 500K, soil cap 3 KSF, 14'-0" sq x 31" d	EACH	1	$1,700.00	$1,600.00	$3,300.00
0111208010	Spread Footings,3000 PSI conc, ld 500K, soil cap 6 KSF, 9'-6" sq x 30" d	EACH	1	$780.00	$840.00	$1,620.00
0111208050	Spread Footings,3000 PSI conc, ld 600K, soil cap 3 KSF, 16'-0" sq x 35" d	EACH	1	$2,500.00	$2,225.00	$4,725.00
0111208100	Spread Footings,3000 PSI conc, ld 600K, soil cap 6 KSF, 10'-6" sq x 33" d	EACH	1	$1,050.00	$1,075.00	$2,125.00
0111208150	Spread Footings,3000 PSI conc, ld 700K, soil cap 3 KSF, 17'-0" sq x 37" d	EACH	1	$2,925.00	$2,525.00	$5,450.00
0111208200	Spread Footings,3000 PSI conc, ld 700K, soil cap 6 KSF, 11'-6" sq x 36" d	EACH	1	$1,350.00	$1,325.00	$2,675.00
0111208250	Spread Footings,3000 PSI conc, ld 800K, soil cap 3 KSF, 18'-0" sq x 39" d	EACH	1	$3,450.00	$2,950.00	$6,400.00
0111208300	Spread Footings,3000 PSI conc, ld 800K, soil cap 6 KSF, 12'-0" sq x 37" d	EACH	1	$1,500.00	$1,450.00	$2,950.00
0111208350	Spread Footings,3000 PSI conc, ld 900K, soil cap 3 KSF, 19'-0" sq x 40" d	EACH	1	$4,000.00	$3,375.00	$7,375.00
0111208400	Spread Footings,3000 PSI conc, ld 900K, soil cap 6 KSF, 13'-0" sq x 39" d	EACH	1	$1,850.00	$1,750.00	$3,600.00

SAMPLE TABLE BY DIVISION OF THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...						
SNumber	Description	Unit	Quantity	Material	Installation	Total
0111208450	Spread Footings,3000 PSI conc,ld 1000K,soil cap 3 KSF,20'-0" sq x 42" d	EACH	1	$4,625.00	$3,800.00	$8,425.00
0111208500	Spread Footings,3000 PSI conc,ld 1000K,soil cap 6 KSF,13'-6" sq x 41" d	EACH	1	$2,100.00	$1,925.00	$4,025.00
0111208550	Spread Footings,3000 PSI conc,ld 1200K,soil cap 6 KSF,15'-0" sq x 48" d	EACH	1	$2,775.00	$2,450.00	$5,225.00
0111208600	Spread Footings,3000 PSI conc,ld 1400K,soil cap 6 KSF,16'-0" sq x 47" d	EACH	1	$3,375.00	$2,925.00	$6,300.00
0111208650	Spread Footings,3000 PSI conc,ld 1600K,soil cap 6 KSF,18'-0" sq x 52" d	EACH	1	$4,675.00	$3,875.00	$8,550.00
0111401900	Strip Footings		1	$0.00	$0.00	$0.00
0111402100	Strip Footing, Load 2.6KLF, Soil Capacity 3KSF, 16" Wide x 8" Deep Plain	L.F.	1	$4.42	$9.15	$13.57
0111402300	Strip Footing, load 3.9 KLF soil cap, 3 KSF, 24" wide x 8" deep, plain	L.F.	1	$5.60	$10.20	$15.80
0111402500	Strip Footing, load 5.1 KLF, soil cap 3 KSF, 24" wide x 12" deep, reinforced	L.F.	1	$8.85	$15.35	$24.20
0111402700	Strip Footing, load 11.1 KLF, soil cap 6 KSF, 24" wide x 12" deep, Reinforced	L.F.	1	$8.85	$15.35	$24.20
0111402900	Strip Footing, load 6.8 KLF, soil cap 3 KSF, 32" wide x 12" deep, reinforced	L.F.	1	$10.95	$16.80	$27.75

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111207100	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.260	C.Y.	$0.00	$0.56	$0.56
0111207100	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	0.590	C.Y.	$0.00	$3.30	$3.30
0111207100	3	Excavate trench, trim sides and bottom for concrete pours, common earth	9.000	S.F.	$0.00	$5.60	$5.60
0111207100	4	Forms in place, dowel supports for footings or beams, 1 use	6.000	L.F.	$5.90	$16.15	$22.00
0111207100	5	Forms in place, footings, spread footings, plywood, 4 use	12.000	SFCA	$7.30	$39.00	$46.00
0111207100	6	Reinforcing in place, footings, #4 to #7	0.006	Ton	$3.51	$4.95	$8.45
0111207100	7	Concrete ready mix, regular weight 3000 psi	0.330	C.Y.	$23.00	$0.00	$23.00
0111207100	8	Placing concrete, footings, spread, over 5 CY, direct chute	0.330	C.Y.	$0.00	$5.05	$5.05
0111207100	9	Finishing floors, monolithic, screed finish	9.000	S.F.	$0.00	$3.24	$3.24
0111207150	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.370	C.Y.	$0.00	$0.79	$0.79
0111207150	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	1.120	C.Y.	$0.00	$6.25	$6.25
0111207150	3	Excavate trench, trim sides and bottom for concrete pours, common earth	20.250	S.F.	$0.00	$12.55	$12.55
0111207150	4	Forms in place, dowel supports for footings or beams, 1 use	9.000	L.F.	$8.80	$24.00	$33.00
0111207150	5	Forms in place, footings, spread footings, plywood, 4 use	18.000	SFCA	$11.00	$58.50	$69.50
0111207150	6	Reinforcing in place, footings, #4 to #7	0.017	Ton	$9.95	$14.05	$24.00
0111207150	7	Concrete ready mix, regular weight 3000 psi	0.750	C.Y.	$52.00	$0.00	$52.00
0111207150	8	Placing concrete, footings, spread, over 5 CY, direct chute	0.750	C.Y.	$0.00	$11.45	$11.45
0111207150	9	Finishing floors, monolithic, screed finish	20.250	S.F.	$0.00	$7.30	$7.30
0111207200	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.260	C.Y.	$0.00	$0.56	$0.56
0111207200	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	0.590	C.Y.	$0.00	$3.30	$3.30
0111207200	3	Excavate trench, trim sides and bottom for concrete pours, common earth	9.000	S.F.	$0.00	$5.60	$5.60
0111207200	4	Forms in place, dowel supports for footings or beams, 1 use	6.000	L.F.	$5.90	$16.15	$22.00
0111207200	5	Forms in place, footings, spread footings, plywood, 4 use	12.000	SFCA	$7.30	$39.00	$46.00
0111207200	6	Reinforcing in place, footings, #4 to #7	0.006	Ton	$3.51	$4.95	$8.45
0111207200	7	Concrete ready mix, regular weight 3000 psi	0.330	C.Y.	$23.00	$0.00	$23.00
0111207200	8	Placing concrete, footings, spread, over 5 CY, direct chute	0.330	C.Y.	$0.00	$5.05	$5.05
0111207200	9	Finishing floors, monolithic, screed finish	9.000	S.F.	$0.00	$3.24	$3.24

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111207250	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.525	C.Y.	$0.00	$1.12	$1.12
0111207250	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	1.750	C.Y.	$0.00	$9.80	$9.80
0111207250	3	Excavate trench, trim sides and bottom for concrete pours, common earth	30.250	S.F.	$0.00	$18.75	$18.75
0111207250	4	Forms in place, dowel supports for footings or beams, 1 use	11.000	L.F.	$10.80	$29.50	$40.50
0111207250	5	Forms in place, footings, spread footings, plywood, 4 use	23.750	SFCA	$14.50	$77.00	$91.50
0111207250	6	Reinforcing in place, footings, #4 to #7	0.031	Ton	$18.15	$25.50	$43.50
0111207250	7	Concrete ready mix, regular weight 3000 psi	1.215	C.Y.	$84.00	$0.00	$84.00
0111207250	8	Placing concrete, footings, spread, over 5 CY, direct chute	1.215	C.Y.	$0.00	$18.55	$18.55
0111207250	9	Finishing floors, monolithic, screed finish	30.250	S.F.	$0.00	$10.90	$10.90
0111207300	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.330	C.Y.	$0.00	$0.71	$0.71
0111207300	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	0.930	C.Y.	$0.00	$5.20	$5.20
0111207300	3	Excavate trench, trim sides and bottom for concrete pours, common earth	16.000	S.F.	$0.00	$9.90	$9.90
0111207300	4	Forms in place, dowel supports for footings or beams, 1 use	8.000	L.F.	$7.85	$21.50	$29.50
0111207300	5	Forms in place, footings, spread footings, plywood, 4 use	16.000	SFCA	$9.75	$52.00	$61.50
0111207300	6	Reinforcing in place, footings, #4 to #7	0.014	Ton	$8.20	$11.55	$19.75
0111207300	7	Concrete ready mix, regular weight 3000 psi	0.590	C.Y.	$40.50	$0.00	$40.50
0111207300	8	Placing concrete, footings, spread, over 5 CY, direct chute	0.590	C.Y.	$0.00	$9.00	$9.00
0111207300	9	Finishing floors, monolithic, screed finish	16.000	S.F.	$0.00	$5.75	$5.75
0111207350	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.660	C.Y.	$0.00	$1.41	$1.41
0111207350	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	2.215	C.Y.	$0.00	$12.40	$12.40
0111207350	3	Excavate trench, trim sides and bottom for concrete pours, common earth	36.000	S.F.	$0.00	$22.50	$22.50
0111207350	4	Forms in place, dowel supports for footings or beams, 1 use	12.000	L.F.	$11.75	$32.50	$44.00
0111207350	5	Forms in place, footings, spread footings, plywood, 4 use	28.000	SFCA	$17.10	$90.50	$108.00
0111207350	6	Reinforcing in place, footings, #4 to #7	0.040	Ton	$23.50	$33.00	$56.50
0111207350	7	Concrete ready mix, regular weight 3000 psi	1.560	C.Y.	$108.00	$0.00	$108.00
0111207350	8	Placing concrete, footings, spread, over 5 CY, direct chute	1.560	C.Y.	$0.00	$24.00	$24.00
0111207350	9	Finishing floors, monolithic, screed finish	36.000	S.F.	$0.00	$12.95	$12.95
0111207410	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.595	C.Y.	$0.00	$1.27	$1.27
0111207410	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	1.533	C.Y.	$0.00	$8.55	$8.55

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111207410	3	Excavate trench, trim sides and bottom for concrete pours, common earth	20.250	S.F.	$0.00	$12.55	$12.55
0111207410	4	Forms in place, dowel supports for footings or beams, 1 use	9.000	L.F.	$8.80	$24.00	$33.00
0111207410	5	Forms in place, footings, spread footings, plywood, 4 use	22.500	SFCA	$13.75	$73.00	$86.50
0111207410	6	Reinforcing in place, footings, #4 to #7	0.021	Ton	$12.30	$17.35	$29.50
0111207410	7	Concrete ready mix, regular weight 3000 psi	0.938	C.Y.	$64.50	$0.00	$64.50
0111207410	8	Placing concrete, footings, spread, over 5 CY, direct chute	0.938	C.Y.	$0.00	$14.30	$14.30
0111207410	9	Finishing floors, monolithic, screed finish	20.250	S.F.	$0.00	$7.30	$7.30
0111207450	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.793	C.Y.	$0.00	$1.70	$1.70
0111207450	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	3.370	C.Y.	$0.00	$18.85	$18.85
0111207450	3	Excavate trench, trim sides and bottom for concrete pours, common earth	49.000	S.F.	$0.00	$30.50	$30.50
0111207450	4	Forms in place, dowel supports for footings or beams, 1 use	16.000	L.F.	$15.70	$43.00	$58.50
0111207450	5	Forms in place, footings, spread footings, plywood, 4 use	39.760	SFCA	$24.50	$129.00	$153.00
0111207450	6	Reinforcing in place, footings, #4 to #7	0.059	Ton	$34.50	$48.50	$83.00
0111207450	7	Concrete ready mix, regular weight 3000 psi	2.577	C.Y.	$178.00	$0.00	$178.00
0111207450	8	Placing concrete, footings, spread, over 5 CY, direct chute	2.577	C.Y.	$0.00	$39.50	$39.50
0111207450	9	Finishing floors, monolithic, screed finish	49.000	S.F.	$0.00	$17.65	$17.65
0111207500	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.539	C.Y.	$0.00	$1.15	$1.15
0111207500	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	1.770	C.Y.	$0.00	$9.90	$9.90
0111207500	3	Excavate trench, trim sides and bottom for concrete pours, common earth	25.000	S.F.	$0.00	$15.50	$15.50
0111207500	4	Forms in place, dowel supports for footings or beams, 1 use	10.000	L.F.	$9.80	$27.00	$36.50
0111207500	5	Forms in place, footings, spread footings, plywood, 4 use	26.600	SFCA	$16.25	$86.00	$102.00
0111207500	6	Reinforcing in place, footings, #4 to #7	0.028	Ton	$16.40	$23.00	$39.50
0111207500	7	Concrete ready mix, regular weight 3000 psi	1.231	C.Y.	$85.00	$0.00	$85.00
0111207500	8	Placing concrete, footings, spread, over 5 CY, direct chute	1.231	C.Y.	$0.00	$18.75	$18.75
0111207500	9	Finishing floors, monolithic, screed finish	25.000	S.F.	$0.00	$9.00	$9.00
0111207550	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	1.375	C.Y.	$0.00	$2.94	$2.94
0111207550	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	4.500	C.Y.	$0.00	$25.00	$25.00
0111207550	3	Excavate trench, trim sides and bottom for concrete pours, common earth	56.250	S.F.	$0.00	$35.00	$35.00
0111207550	4	Forms in place, dowel supports for footings or beams, 1 use	17.000	L.F.	$16.65	$45.50	$62.50
0111207550	5	Forms in place, footings, spread footings, plywood, 4 use	45.000	SFCA	$27.50	$146.00	$173.00

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111207550	6	Reinforcing in place, footings, #4 to #7	0.074	Ton	$43.50	$61.00	$104.00
0111207550	7	Concrete ready mix, regular weight 3000 psi	3.125	C.Y.	$216.00	$0.00	$216.00
0111207550	8	Placing concrete, footings, spread, over 5 CY, direct chute	3.125	C.Y.	$0.00	$47.50	$47.50
0111207550	9	Finishing floors, monolithic, screed finish	56.250	S.F.	$0.00	$20.50	$20.50
0111207610	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	1.045	C.Y.	$0.00	$2.24	$2.24
0111207610	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	2.725	C.Y.	$0.00	$15.25	$15.25
0111207610	3	Excavate trench, trim sides and bottom for concrete pours, common earth	30.250	S.F.	$0.00	$18.75	$18.75
0111207610	4	Forms in place, dowel supports for footings or beams, 1 use	11.000	L.F.	$10.80	$29.50	$40.50
0111207610	5	Forms in place, footings, spread footings, plywood, 4 use	33.000	SFCA	$20.00	$107.00	$127.00
0111207610	6	Reinforcing in place, footings, #4 to #7	0.037	Ton	$21.50	$30.50	$52.00
0111207610	7	Concrete ready mix, regular weight 3000 psi	1.680	C.Y.	$116.00	$0.00	$116.00
0111207610	8	Placing concrete, footings, spread, over 5 CY, direct chute	1.680	C.Y.	$0.00	$25.50	$25.50
0111207610	9	Finishing floors, monolithic, screed finish	30.250	S.F.	$0.00	$10.90	$10.90
0111207650	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	1.950	C.Y.	$0.00	$4.17	$4.17
0111207650	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	6.400	C.Y.	$0.00	$36.00	$36.00
0111207650	3	Excavate trench, trim sides and bottom for concrete pours, common earth	72.250	S.F.	$0.00	$45.00	$45.00
0111207650	4	Forms in place, dowel supports for footings or beams, 1 use	19.000	L.F.	$18.60	$51.00	$69.50
0111207650	5	Forms in place, footings, spread footings, plywood, 4 use	56.750	SFCA	$34.50	$184.00	$218.00
0111207650	6	Reinforcing in place, footings, #4 to #7	0.114	Ton	$66.50	$94.00	$161.00
0111207650	7	Concrete ready mix, regular weight 3000 psi	4.470	C.Y.	$310.00	$0.00	$310.00
0111207650	8	Placing concrete, footings, spread, over 5 CY, direct chute	4.470	C.Y.	$0.00	$68.00	$68.00
0111207650	9	Finishing floors, monolithic, screed finish	72.250	S.F.	$0.00	$26.00	$26.00
0111207700	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	1.410	C.Y.	$0.00	$3.02	$3.02
0111207700	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	3.640	C.Y.	$0.00	$20.50	$20.50
0111207700	3	Excavate trench, trim sides and bottom for concrete pours, common earth	36.000	S.F.	$0.00	$22.50	$22.50
0111207700	4	Forms in place, dowel supports for footings or beams, 1 use	12.000	L.F.	$11.75	$32.50	$44.00
0111207700	5	Forms in place, footings, spread footings, plywood, 4 use	40.000	SFCA	$24.50	$130.00	$154.00
0111207700	6	Reinforcing in place, footings, #4 to #7	0.050	Ton	$29.50	$41.50	$70.50
0111207700	7	Concrete ready mix, regular weight 3000 psi	2.230	C.Y.	$154.00	$0.00	$154.00

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...

SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111207700	8	Placing concrete, footings, spread, over 5 CY, direct chute	2.230	C.Y.	$0.00	$34.00	$34.00
0111207700	9	Finishing floors, monolithic, screed finish	36.000	S.F.	$0.00	$12.95	$12.95
0111207750	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	3.710	C.Y.	$0.00	$7.95	$7.95
0111207750	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	12.215	C.Y.	$0.00	$68.50	$68.50
0111207750	3	Excavate trench, trim sides and bottom for concrete pours, common earth	110.250	S.F.	$0.00	$68.50	$68.50
0111207750	4	Forms in place, dowel supports for footings or beams, 1 use	23.000	L.F.	$22.50	$62.00	$84.50
0111207750	5	Forms in place, footings, spread footings, plywood, 4 use	87.500	SFCA	$53.50	$284.00	$335.00
0111207750	6	Reinforcing in place, footings, #4 to #7	0.204	Ton	$119.00	$168.00	$288.00
0111207750	7	Concrete ready mix, regular weight 3000 psi	8.505	C.Y.	$585.00	$0.00	$585.00
0111207750	8	Placing concrete, footings, spread, over 5 CY, direct chute	8.505	C.Y.	$0.00	$130.00	$130.00
0111207750	9	Finishing floors, monolithic, screed finish	110.250	S.F.	$0.00	$39.50	$39.50
0111207810	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	2.750	C.Y.	$0.00	$5.90	$5.90
0111207810	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	7.085	C.Y.	$0.00	$39.50	$39.50
0111207810	3	Excavate trench, trim sides and bottom for concrete pours, common earth	56.250	S.F.	$0.00	$35.00	$35.00
0111207810	4	Forms in place, dowel supports for footings or beams, 1 use	17.000	L.F.	$16.65	$45.50	$62.50
0111207810	5	Forms in place, footings, spread footings, plywood, 4 use	62.500	SFCA	$38.00	$203.00	$241.00
0111207810	6	Reinforcing in place, footings, #4 to #7	0.100	Ton	$58.50	$82.50	$141.00
0111207810	7	Concrete ready mix, regular weight 3000 psi	4.330	C.Y.	$299.00	$0.00	$299.00
0111207810	8	Placing concrete, footings, spread, over 5 CY, direct chute	4.330	C.Y.	$0.00	$66.00	$66.00
0111207810	9	Finishing floors, monolithic, screed finish	56.250	S.F.	$0.00	$20.50	$20.50
0111207850	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	7.249	C.Y.	$0.00	$15.50	$15.50
0111207850	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	20.733	C.Y.	$0.00	$116.00	$116.00
0111207850	3	Excavate trench, trim sides and bottom for concrete pours, common earth	156.250	S.F.	$0.00	$97.00	$97.00
0111207850	4	Forms in place, dowel supports for footings or beams, 1 use	27.000	L.F.	$26.50	$72.50	$99.00
0111207850	5	Forms in place, footings, spread footings, plywood, 4 use	116.500	SFCA	$71.00	$375.00	$450.00
0111207850	6	Reinforcing in place, footings, #4 to #7	0.352	Ton	$206.00	$290.00	$495.00
0111207850	7	Concrete ready mix, regular weight 3000 psi	13.480	C.Y.	$930.00	$0.00	$930.00
0111207850	8	Placing concrete, footings, spread, over 5 CY, direct chute	13.480	C.Y.	$0.00	$206.00	$206.00
0111207850	9	Finishing floors, monolithic, screed finish	156.250	S.F.	$0.00	$56.50	$56.50

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...

SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111207900	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	3.610	C.Y.	$0.00	$7.75	$7.75
0111207900	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	9.630	C.Y.	$0.00	$54.00	$54.00
0111207900	3	Excavate trench, trim sides and bottom for concrete pours, common earth	72.250	S.F.	$0.00	$45.00	$45.00
0111207900	4	Forms in place, dowel supports for footings or beams, 1 use	19.000	L.F.	$18.60	$51.00	$69.50
0111207900	5	Forms in place, footings, spread footings, plywood, 4 use	76.500	SFCA	$46.50	$248.00	$295.00
0111207900	6	Reinforcing in place, footings, #4 to #7	0.150	Ton	$88.00	$124.00	$212.00
0111207900	7	Concrete ready mix, regular weight 3000 psi	6.025	C.Y.	$415.00	$0.00	$415.00
0111207900	8	Placing concrete, footings, spread, over 5 CY, direct chute	6.025	C.Y.	$0.00	$92.00	$92.00
0111207900	9	Finishing floors, monolithic, screed finish	72.250	S.F.	$0.00	$26.00	$26.00
0111207950	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	8.890	C.Y.	$0.00	$19.00	$19.00
0111207950	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	27.620	C.Y.	$0.00	$154.00	$154.00
0111207950	3	Excavate trench, trim sides and bottom for concrete pours, common earth	196.000	S.F.	$0.00	$122.00	$122.00
0111207950	4	Forms in place, dowel supports for footings or beams, 1 use	30.000	L.F.	$29.50	$80.50	$110.00
0111207950	5	Forms in place, footings, spread footings, plywood, 4 use	144.480	SFCA	$88.00	$470.00	$555.00
0111207950	6	Reinforcing in place, footings, #4 to #7	0.505	Ton	$295.00	$415.00	$710.00
0111207950	7	Concrete ready mix, regular weight 3000 psi	18.729	C.Y.	$1,300.0	$0.00	$1,300.00
0111207950	8	Placing concrete, footings, spread, over 5 CY, direct chute	18.729	C.Y.	$0.00	$286.00	$286.00
0111207950	9	Finishing floors, monolithic, screed finish	196.000	S.F.	$0.00	$70.50	$70.50
0111208010	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	4.975	C.Y.	$0.00	$10.65	$10.65
0111208010	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	13.330	C.Y.	$0.00	$74.50	$74.50
0111208010	3	Excavate trench, trim sides and bottom for concrete pours, common earth	90.250	S.F.	$0.00	$56.00	$56.00
0111208010	4	Forms in place, dowel supports for footings or beams, 1 use	21.000	L.F.	$20.50	$56.50	$77.00
0111208010	5	Forms in place, footings, spread footings, plywood, 4 use	95.000	SFCA	$58.00	$310.00	$365.00
0111208010	6	Reinforcing in place, footings, #4 to #7	0.214	Ton	$125.00	$177.00	$300.00
0111208010	7	Concrete ready mix, regular weight 3000 psi	8.350	C.Y.	$575.00	$0.00	$575.00
0111208010	8	Placing concrete, footings, spread, over 5 CY, direct chute	8.350	C.Y.	$0.00	$127.00	$127.00
0111208010	9	Finishing floors, monolithic, screed finish	90.250	S.F.	$0.00	$32.50	$32.50
0111208050	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	11.000	C.Y.	$0.00	$23.50	$23.50
0111208050	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	38.670	C.Y.	$0.00	$216.00	$216.00

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111208050	3	Excavate trench, trim sides and bottom for concrete pours, common earth	256.000	S.F.	$0.00	$159.00	$159.00
0111208050	4	Forms in place, dowel supports for footings or beams, 1 use	34.000	L.F.	$33.50	$91.50	$125.00
0111208050	5	Forms in place, footings, spread footings, plywood, 4 use	187.500	SFCA	$114.00	$610.00	$720.00
0111208050	6	Reinforcing in place, footings, #4 to #7	0.738	Ton	$430.00	$610.00	$1,050.00
0111208050	7	Concrete ready mix, regular weight 3000 psi	27.670	C.Y.	$1,900.0	$0.00	$1,900.00
0111208050	8	Placing concrete, footings, spread, over 5 CY, direct chute	27.670	C.Y.	$0.00	$420.00	$420.00
0111208050	9	Finishing floors, monolithic, screed finish	256.000	S.F.	$0.00	$92.00	$92.00
0111208100	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	7.334	C.Y.	$0.00	$15.70	$15.70
0111208100	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	18.563	C.Y.	$0.00	$104.00	$104.00
0111208100	3	Excavate trench, trim sides and bottom for concrete pours, common earth	110.250	S.F.	$0.00	$68.50	$68.50
0111208100	4	Forms in place, dowel supports for footings or beams, 1 use	23.000	L.F.	$22.50	$62.00	$84.50
0111208100	5	Forms in place, footings, spread footings, plywood, 4 use	115.500	SFCA	$70.50	$375.00	$445.00
0111208100	6	Reinforcing in place, footings, #4 to #7	0.306	Ton	$179.00	$252.00	$430.00
0111208100	7	Concrete ready mix, regular weight 3000 psi	11.229	C.Y.	$775.00	$0.00	$775.00
0111208100	8	Placing concrete, footings, spread, over 5 CY, direct chute	11.229	C.Y.	$0.00	$171.00	$171.00
0111208100	9	Finishing floors, monolithic, screed finish	110.250	S.F.	$0.00	$39.50	$39.50
0111208150	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	12.662	C.Y.	$0.00	$27.00	$27.00
0111208150	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	45.630	C.Y.	$0.00	$255.00	$255.00
0111208150	3	Excavate trench, trim sides and bottom for concrete pours, common earth	289.000	S.F.	$0.00	$179.00	$179.00
0111208150	4	Forms in place, dowel supports for footings or beams, 1 use	36.000	L.F.	$35.50	$97.00	$132.00
0111208150	5	Forms in place, footings, spread footings, plywood, 4 use	209.440	SFCA	$128.00	$680.00	$805.00
0111208150	6	Reinforcing in place, footings, #4 to #7	0.841	Ton	$490.00	$695.00	$1,175.00
0111208150	7	Concrete ready mix, regular weight 3000 psi	32.967	C.Y.	$2,275.0	$0.00	$2,275.00
0111208150	8	Placing concrete, footings, spread, over 5 CY, direct chute	32.967	C.Y.	$0.00	$505.00	$505.00
0111208150	9	Finishing floors, monolithic, screed finish	289.000	S.F.	$0.00	$104.00	$104.00
0111208200	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	8.665	C.Y.	$0.00	$18.55	$18.55
0111208200	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	23.361	C.Y.	$0.00	$131.00	$131.00
0111208200	3	Excavate trench, trim sides and bottom for concrete pours, common earth	132.250	S.F.	$0.00	$82.00	$82.00
0111208200	4	Forms in place, dowel supports for footings or beams, 1 use	25.000	L.F.	$24.50	$67.50	$92.00

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111208200	5	Forms in place, footings, spread footings, plywood, 4 use	138.000	SFCA	$84.00	$445.00	$530.00
0111208200	6	Reinforcing in place, footings, #4 to #7	0.374	Ton	$219.00	$310.00	$525.00
0111208200	7	Concrete ready mix, regular weight 3000 psi	14.694	C.Y.	$1,025.0	$0.00	$1,025.00
0111208200	8	Placing concrete, footings, spread, over 5 CY, direct chute	14.694	C.Y.	$0.00	$224.00	$224.00
0111208200	9	Finishing floors, monolithic, screed finish	132.250	S.F.	$0.00	$47.50	$47.50
0111208250	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	15.375	C.Y.	$0.00	$33.00	$33.00
0111208250	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	54.375	C.Y.	$0.00	$305.00	$305.00
0111208250	3	Excavate trench, trim sides and bottom for concrete pours, common earth	324.000	S.F.	$0.00	$201.00	$201.00
0111208250	4	Forms in place, dowel supports for footings or beams, 1 use	38.000	L.F.	$37.00	$102.00	$139.00
0111208250	5	Forms in place, footings, spread footings, plywood, 4 use	234.000	SFCA	$143.00	$760.00	$900.00
0111208250	6	Reinforcing in place, footings, #4 to #7	1.011	Ton	$590.00	$835.00	$1,425.00
0111208250	7	Concrete ready mix, regular weight 3000 psi	39.000	C.Y.	$2,700.0	$0.00	$2,700.00
0111208250	8	Placing concrete, footings, spread, over 5 CY, direct chute	39.000	C.Y.	$0.00	$595.00	$595.00
0111208250	9	Finishing floors, monolithic, screed finish	324.000	S.F.	$0.00	$117.00	$117.00
0111208300	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	9.239	C.Y.	$0.00	$19.75	$19.75
0111208300	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	25.667	C.Y.	$0.00	$143.00	$143.00
0111208300	3	Excavate trench, trim sides and bottom for concrete pours, common earth	144.000	S.F.	$0.00	$89.50	$89.50
0111208300	4	Forms in place, dowel supports for footings or beams, 1 use	26.000	L.F.	$25.50	$70.00	$95.50
0111208300	5	Forms in place, footings, spread footings, plywood, 4 use	147.840	SFCA	$90.00	$480.00	$570.00
0111208300	6	Reinforcing in place, footings, #4 to #7	0.430	Ton	$252.00	$355.00	$605.00
0111208300	7	Concrete ready mix, regular weight 3000 psi	16.427	C.Y.	$11.25	$0.00	$11.25
0111208300	8	Placing concrete, footings, spread, over 5 CY, direct chute	16.427	C.Y.	$0.00	$251.00	$251.00
0111208300	9	Finishing floors, monolithic, screed finish	144.000	S.F.	$0.00	$52.00	$52.00
0111208350	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	15.170	C.Y.	$0.00	$32.50	$32.50
0111208350	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	59.693	C.Y.	$0.00	$335.00	$335.00
0111208350	3	Excavate trench, trim sides and bottom for concrete pours, common earth	361.000	S.F.	$0.00	$224.00	$224.00
0111208350	4	Forms in place, dowel supports for footings or beams, 1 use	40.000	L.F.	$39.00	$108.00	$147.00
0111208350	5	Forms in place, footings, spread footings, plywood, 4 use	253.080	SFCA	$154.00	$820.00	$975.00
0111208350	6	Reinforcing in place, footings, #4 to #7	1.274	Ton	$745.00	$1,050.00	$1,800.00

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111208350	7	Concrete ready mix, regular weight 3000 psi	44.523	C.Y.	$3,075.0	$0.00	$3,075.00
0111208350	8	Placing concrete, footings, spread, over 5 CY, direct chute	44.523	C.Y.	$0.00	$680.00	$680.00
0111208350	9	Finishing floors, monolithic, screed finish	361.000	S.F.	$0.00	$130.00	$130.00
0111208400	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	10.472	C.Y.	$0.00	$22.50	$22.50
0111208400	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	30.815	C.Y.	$0.00	$172.00	$172.00
0111208400	3	Excavate trench, trim sides and bottom for concrete pours, common earth	169.000	S.F.	$0.00	$105.00	$105.00
0111208400	4	Forms in place, dowel supports for footings or beams, 1 use	28.000	L.F.	$27.50	$75.50	$103.00
0111208400	5	Forms in place, footings, spread footings, plywood, 4 use	169.000	SFCA	$103.00	$550.00	$650.00
0111208400	6	Reinforcing in place, footings, #4 to #7	0.538	Ton	$315.00	$445.00	$760.00
0111208400	7	Concrete ready mix, regular weight 3000 psi	20.343	C.Y.	$1,400.0	$0.00	$1,400.00
0111208400	8	Placing concrete, footings, spread, over 5 CY, direct chute	20.343	C.Y.	$0.00	$310.00	$310.00
0111208400	9	Finishing floors, monolithic, screed finish	169.000	S.F.	$0.00	$61.00	$61.00
0111208450	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	16.722	C.Y.	$0.00	$36.00	$36.00
0111208450	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	68.574	C.Y.	$0.00	$385.00	$385.00
0111208450	3	Excavate trench, trim sides and bottom for concrete pours, common earth	400.000	S.F.	$0.00	$248.00	$248.00
0111208450	4	Forms in place, dowel supports for footings or beams, 1 use	42.000	L.F.	$41.00	$113.00	$154.00
0111208450	5	Forms in place, footings, spread footings, plywood, 4 use	280.000	SFCA	$171.00	$905.00	$1,075.00
0111208450	6	Reinforcing in place, footings, #4 to #7	1.426	Ton	$835.00	$1,175.00	$2,000.00
0111208450	7	Concrete ready mix, regular weight 3000 psi	51.850	C.Y.	$3,575.0	$0.00	$3,575.00
0111208450	8	Placing concrete, footings, spread, over 5 CY, direct chute	51.850	C.Y.	$0.00	$790.00	$790.00
0111208450	9	Finishing floors, monolithic, screed finish	400.000	S.F.	$0.00	$144.00	$144.00
0111208500	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	11.400	C.Y.	$0.00	$24.50	$24.50
0111208500	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	34.485	C.Y.	$0.00	$193.00	$193.00
0111208500	3	Excavate trench, trim sides and bottom for concrete pours, common earth	182.250	S.F.	$0.00	$113.00	$113.00
0111208500	4	Forms in place, dowel supports for footings or beams, 1 use	29.000	L.F.	$28.50	$78.00	$106.00
0111208500	5	Forms in place, footings, spread footings, plywood, 4 use	184.680	SFCA	$113.00	$600.00	$710.00
0111208500	6	Reinforcing in place, footings, #4 to #7	0.615	Ton	$360.00	$505.00	$865.00
0111208500	7	Concrete ready mix, regular weight 3000 psi	23.085	C.Y.	$1,600.0	$0.00	$1,600.00
0111208500	8	Placing concrete, footings, spread, over 5 CY, direct chute	23.085	C.Y.	$0.00	$350.00	$350.00

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111208500	9	Finishing floors, monolithic, screed finish	182.250	S.F.	$0.00	$65.50	$65.50
0111208550	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	13.457	C.Y.	$0.00	$29.00	$29.00
0111208550	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	44.040	C.Y.	$0.00	$246.00	$246.00
0111208550	3	Excavate trench, trim sides and bottom for concrete pours, common earth	225.000	S.F.	$0.00	$140.00	$140.00
0111208550	4	Forms in place, dowel supports for footings or beams, 1 use	32.000	L.F.	$31.50	$86.00	$117.00
0111208550	5	Forms in place, footings, spread footings, plywood, 4 use	220.000	SFCA	$134.00	$715.00	$845.00
0111208550	6	Reinforcing in place, footings, #4 to #7	0.847	Ton	$495.00	$700.00	$1,200.00
0111208550	7	Concrete ready mix, regular weight 3000 psi	30.583	C.Y.	$2,100.0	$0.00	$2,100.00
0111208550	8	Placing concrete, footings, spread, over 5 CY, direct chute	30.583	C.Y.	$0.00	$465.00	$465.00
0111208550	9	Finishing floors, monolithic, screed finish	225.000	S.F.	$0.00	$81.00	$81.00
0111208600	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	15.244	C.Y.	$0.00	$32.50	$32.50
0111208600	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	52.411	C.Y.	$0.00	$293.00	$293.00
0111208600	3	Excavate trench, trim sides and bottom for concrete pours, common earth	256.000	S.F.	$0.00	$159.00	$159.00
0111208600	4	Forms in place, dowel supports for footings or beams, 1 use	34.000	L.F.	$33.50	$91.50	$125.00
0111208600	5	Forms in place, footings, spread footings, plywood, 4 use	250.880	SFCA	$153.00	$815.00	$965.00
0111208600	6	Reinforcing in place, footings, #4 to #7	1.071	Ton	$625.00	$885.00	$1,500.00
0111208600	7	Concrete ready mix, regular weight 3000 psi	37.167	C.Y.	$2,575.0	$0.00	$2,575.00
0111208600	8	Placing concrete, footings, spread, over 5 CY, direct chute	37.167	C.Y.	$0.00	$565.00	$565.00
0111208600	9	Finishing floors, monolithic, screed finish	256.000	S.F.	$0.00	$92.00	$92.00
0111208650	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	18.763	C.Y.	$0.00	$40.00	$40.00
0111208650	2	Excavating, bulk bank measure, hydrolic excavator, trick mtd, 1/2 CY=30CY/hr	70.723	C.Y.	$0.00	$395.00	$395.00
0111208650	3	Excavate trench, trim sides and bottom for concrete pours, common earth	324.000	S.F.	$0.00	$201.00	$201.00
0111208650	4	Forms in place, dowel supports for footings or beams, 1 use	38.000	L.F.	$37.00	$102.00	$139.00
0111208650	5	Forms in place, footings, spread footings, plywood, 4 use	311.760	SFCA	$190.00	$1,000.00	$1,200.00
0111208650	6	Reinforcing in place, footings, #4 to #7	1.488	Ton	$870.00	$1,225.00	$2,100.00
0111208650	7	Concrete ready mix, regular weight 3000 psi	51.960	C.Y.	$3,575.0	$0.00	$3,575.00
0111208650	8	Placing concrete, footings, spread, over 5 CY, direct chute	51.960	C.Y.	$0.00	$790.00	$790.00
0111208650	9	Finishing floors, monolithic, screed finish	324.000	S.F.	$0.00	$117.00	$117.00
0111402100	1	Backfill, Dozer Backfilling, Compacting, 6" t 12" lifts, Vib rlr	0.032	C.Y.	$0.00	$0.07	$0.07

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111402100	10	Finishing floors, monolithic, screed & foat finish	1.330	S.F.	$0.00	$0.59	$0.59
0111402100	2	Excavate Trench, Continuous Footing, no Showring or Dewatering, 1-4' D, 3/8	0.099	C.Y.	$0.00	$0.56	$0.56
0111402100	3	Excavate Trench, Trim sids & bottom for concrete pours, common earth	1.330	S.F.	$0.00	$0.82	$0.82
0111402100	4	Forms in place, footings, continuous wall, plywood, 4 use	1.340	SFCA	$1.05	$3.71	$4.76
0111402100	5	Forms in place, footings, keyway, 4 use, tapered wood, 2" x 6"	1.000	L.F.	$0.32	$0.71	$1.03
0111402100	6	Reinforcing in place, footings, # 4 to # 7	1.000	Lb.	$0.32	$0.41	$0.73
0111402100	7	Reinforcing in place, dowels, 2' long, deformed, # 4	1.000	Ea.	$0.45	$1.81	$2.26
0111402100	8	Concrete ready mix, regular weight 3000 psi	0.033	C.Y.	$2.28	$0.00	$2.28
0111402100	9	Placing concrete, footings, continuous, shallow, direct chute	0.033	C.Y.	$0.00	$0.50	$0.50
0111402300	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.049	C.Y.	$0.00	$0.10	$0.10
0111402300	10	Finishing floors, monolithic, screed & float finish	2.000	S.F.	$0.00	$0.88	$0.88
0111402300	2	Excavate trench, continuous footing, no shoring or dewatering, 1-4'D, 3/8 CY	0.099	C.Y.	$0.00	$0.56	$0.56
0111402300	3	Excavate trench, trim sides & bottom for concrete pours, common earth	2.000	S.F.	$0.00	$1.24	$1.24
0111402300	4	Forms in place, footings, continuous wall, plywood, 4 use	1.340	SFCA	$1.05	$3.71	$4.76
0111402300	5	Forms in place, footings, keyway, 4 use, tapered wood 2" x 6"	1.000	L.F.	$0.32	$0.71	$1.03
0111402300	6	Reinforcing in place, footings, # 4 to # 7	1.000	Lb.	$0.32	$0.41	$0.73
0111402300	7	Reinforcing in place, dowels, 2' long, deformed, # 4	1.000	Ea.	$0.45	$1.81	$2.26
0111402300	8	Concrete ready mix, regular weight 3000 psi	0.050	C.Y.	$3.45	$0.00	$3.45
0111402300	9	Placing Concrete, footings, continuous, shallow, direct chute	0.050	C.Y.	$0.00	$0.76	$0.76
0111402500	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.074	C.Y.	$0.00	$0.16	$0.16
0111402500	10	Finishing floors, monolithic, screed & Float finish	2.000	S.F.	$0.00	$0.88	$0.88
0111402500	2	Excavate trench, continuous footing, no shoring or dewatering, 1-4'D, 3/8 CY	0.148	C.Y.	$0.00	$0.84	$0.84
0111402500	3	Excavate trench, trim sides & bottom for concrete pours, common earth	2.000	S.F.	$0.00	$1.24	$1.24
0111402500	4	Forms in place, footings, continuous wall, plywood, 4 use	2.000	SFCA	$1.56	$5.55	$7.10
0111402500	5	Forms in place, footings, keyway, 4 use, tapered wood, 2" x 6"	1.000	L.F.	$0.32	$0.71	$1.03
0111402500	6	Reinforcing in place, footings, # 4 to # 7	3.000	Lb.	$0.96	$1.23	$2.19
0111402500	7	Reinforcing in place, dowels, 2' long, deformed, # 4	2.000	Ea.	$0.90	$3.62	$4.52
0111402500	8	Concrete ready mix, regular weight 3000 psi	0.074	C.Y.	$5.10	$0.00	$5.10
0111402500	9	Placing concrete, footings, continuous, shallow, direct chute	0.074	C.Y.	$0.00	$1.13	$1.13

SAMPLE TABLE BY ELEMENTS FOR THE ASSEMBLY DATABASE FOR PRELIMINARY ESTIMATE continue...							
SNumber	ENumbe	Description	Quantity	Unit	Material	Installation	Total
0111402700	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.074	C.Y.	$0.00	$0.16	$0.16
0111402700	10	Finishing floors, monolithic, screed & Float finish	2.000	S.F.	$0.00	$0.88	$0.88
0111402700	2	Excavate trench, continuous footing, no shoring or dewatering, 1-4'D, 3/8 CY	0.148	C.Y.	$0.00	$0.84	$0.84
0111402700	3	Excavate trench, trim sides & bottom for concrete pours, common earth	2.000	S.F.	$0.00	$1.24	$1.24
0111402700	4	Forms in place, footings, continuous wall, plywood, 4 use	2.000	SFCA	$1.56	$5.55	$7.10
0111402700	5	Forms in place, footings, keyway, 4 use, tapered wood, 2" x 6"	1.000	L.F.	$0.32	$0.71	$1.03
0111402700	6	Reinforcing in place, footings, # 4 to # 7	3.000	Lb.	$0.96	$1.23	$2.19
0111402700	7	Reinforcing in place, dowels, 2' long, deformed, # 4	2.000	Ea.	$0.90	$3.62	$4.52
0111402700	8	Concrete ready mix, regular weight 3000 psi	0.074	C.Y.	$5.10	$0.00	$5.10
0111402700	9	Placing concrete, footings, continuous, shallow, direct chute	0.074	C.Y.	$0.00	$1.13	$1.13
0111402900	1	Backfill, dozer backfilling, compacting, 6" to 12" lifts, vib rlr	0.049	C.Y.	$0.00	$0.10	$0.10
0111402900	10	Finishing floors, monolithic, screed & Float finish	2.670	S.F.	$0.00	$1.17	$1.17
0111402900	2	Excavate trench, continuous footing, no shoring or dewatering, 1-4'D, 3/8 CY	0.148	C.Y.	$0.00	$0.84	$0.84
0111402900	3	Excavate trench, trim sides & bottom for concrete pours, common earth	2.670	S.F.	$0.00	$1.66	$1.66
0111402900	4	Forms in place, footings, continuous wall, plywood, 4 use	2.000	SFCA	$1.56	$5.55	$7.10
0111402900	5	Forms in place, footings, keyway, 4 use, tapered wood, 2" x 6"	1.000	L.F.	$0.32	$0.71	$1.03
0111402900	6	Reinforcing in place, footings, # 4 to # 7	4.130	Lb.	$1.32	$1.69	$3.01
0111402900	7	Reinforcing in place, dowels, 2' long, deformed, # 4	2.000	Ea.	$0.90	$3.62	$4.52
0111402900	8	Concrete ready mix, regular weight 3000 psi	0.099	C.Y.	$6.85	$0.00	$6.85
0111402900	9	Placing concrete, footings, continuous, shallow, direct chute	0.099	C.Y.	$0.00	$1.51	$1.51

APPENDIX (D)

ACTUAL PROJECT COST DATA

GENERAL REQUIREMENTS DIVISION (1)			
Code	Project ID	Description	Cost
010400	195	COORDINATION - FOREMAN	$192.28
010421	195	SITE CLERK	$101,495.60
010501	195	SITE LAYOUT - LABOUR	$12,585.38
012003	195	FIRST AID & SAFETY	$2,868.57
015110	195	TEMPORARY ELECTRICITY/LIGHTS	$14,852.68
015130	195	TEMPORARY HEATING	$35,376.52
015140	195	TEMPORARY TELEPHONE SERVICE	$10,140.68
015160	195	TEMPORARY SANITARY	$4,331.98
015311	195	TEMP FENCES & HOARDING	$4,592.57
015314	195	FENCES & HOARDING - SUBCONT	$3,853.05
015401	195	SECURITY	$111,215.13
015900	195	OFFICES & SHEDS	$10,099.62
016003	195	SMALL TOOLS & EQUIPMENT	$28,803.28
017101	195	CLEANING - LABOUR	$147,912.63
017102	195	CLEANING - EQUIPMENT	$57,675.12
017104	195	CLEANING SUB	$26,376.42
018000	195	SITE COSTS (MISC. ONLY)	$5,646.33
018100	195	CARTAGE	$1,472.71

SITE WORK DIVISION (2)			
Code	Project ID	Description	Cost
020504	195	DEMOLITION	$209.68
021000	195	SITE PREP/CLEARING/GRADING	$49,912.13
022191	195	STRUCTURE/BACKFILL/COMPACT	$15,273.08
022192	195	STRUCTURE/BACKFILL/COMPACT	$65,435.45
022193	195	STRUCTURE BACKFILL &	$57,099.78
022204	195	STRUCTURE EXCAVATION	$275,005.09
022211	195	TRENCH/BKFILL/COMPACT-LABOUR	$7,964.46
022221	195	SAND & GRAVEL - LABOUR	$69,893.97
022222	195	SAND & GRAVEL - EQUIPMENT	$74,397.13
022223	195	SAND & GRAVEL MATERIAL	$110,102.63
022233	195	SAND & GRAVEL - MATERIAL	$0.00
022300	195	ROAD EXC. BACKFILL & COMP	$104,314.59
024011	195	DEWATERING - LABOUR	$4,998.17
024111	195	FOUNDATION DRAINAGE - LABOUR	$26,848.42
024112	195	FOUNDATION DRAINAGE	$10,807.98
024113	195	FOUNDATION DRAINAGE -	$64,452.67
024414	195	IRRIGATION	$58,113.17
024444	195	FENCES & GATES SUB	$197,778.51
024801	195	LANDSCAPING LABOUR	$47,746.93
024803	195	LANDSCAPING	$83,423.92
024804	195	LANDSCAPING - SUB	$242,288.14

SITE WORK DIVISION (2) continue....			
Code	Project ID	Description	Cost
025004	195	PAVING & SURFACING	$97,491.19
025050	195	PAVER TILE	$57,656.00
025150	195	SIDEWALKS	$45,781.33
027120	195	SANITARY SITEWORK	$118,100.00
027130	195	WATER SITEWORK	$77,130.00
027210	195	STORM SEWER SITEWORK	$130,050.00
028100	195	POWER UTILITIES	$20,000.00
028210	195	TELEPHONE SITEWORKS	$45,511.50

CONCRETE DIVISION (3)			
Code	Project ID	Description	Cost
031501	195	FORMS - LABOUR	$7,424.60
031503	195	FORMS - MATERIAL	$34,175.48
031504	195	FORMS - SUBCONTRACT	$236,203.09
031800	195	FORM TIES & ACCESSORIES	$4,266.33
032004	195	CONCRETE REINFORCEMENT	$99,627.63
033003	195	CAST-IN-PLACE CONCRETE	$276,490.56
033450	195	CONCRETE FINISHING	$41,848.64
033500	195	SPECIAL CONCRETE FINISHES	$46,031.34
036000	195	MORTAR/GROUT/PLANO	$15,512.46

MASONRY DIVISION (4)			
Code	Project ID	Description	Cost
042104	195	BRICK MASONRY	$9,470.00

METALS DIVISION (5)			
Code	Project	Description	Cost
050513	195	METAL FASTENING - NAILS	$11,150.58
055204	195	HANDRAILS & RAILINGS, SUB	$4,776.16

WOOD AND PLASTICS DIVISION (6)			
Code	Project	Description	Cost
061001	195	ROUGH CARPENTRY	$123,822.57
061003	195	ROUGH CARPENTRY - MATERIALS	$766,432.83
061004	195	ROUGH CARPENTRY - SUB	$332,007.63
061904	195	WOOD TRUSSES	$373,958.43
062000	195	FINISHED CARPENTRY	$1,124.61
062001	195	FINISH CARPENTRY - LABOUR	$178,707.23
062004	195	FINISH CARP. SUB	$77,638.75
062243	195	CLOSET & STORAGE SHELVING	$24,953.15

WOOD AND PLASTICS DIVISION (6) continue...			
Code	Project	Description	Cost
062253	195	MOULDING & TRIM - MAT'S	$49,414.76
064430	195	STAIRWORK & HANDRAILS	$34,624.21

THERMAL AND MOSITURE DIVISION (7)			
Code	Project	Description	Cost
071500	195	DAMPROOFING	$1,876.89
071533	195	POLY	$7,988.78
072104	195	BLDG INSUL - FIBERGLASS	$142,386.25
072120	195	RIGID INSULATION - PARKING	$72,767.20
072700	195	FIRESTOPPING	$4,969.82
074604	195	CLADDING - SUB	$557,823.38
075100	195	BUILT UP ROOFING	$234,620.25
076304	195	GUTTERS & DOWNPIPE	$25,637.31
076610	195	SHEET METAL ROOFING	$8,500.00
079000	195	JOINT SEALERS CAULKING	$18,110.46

DOORS AND WINDOWS DIVISION (8)			
Code	Project	Description	Cost
082213	195	WOOD DOORS & FRAMES	$199,362.21
083604	195	OVERHEAD DOORS SUB	$73,197.86
085004	195	RES METAL WINDOWS - SUB	$183,050.48

FINISHES DIVISION (9)			
Code	Project	Description	Cost
092004	195	GYPSUM BOARD, TAPE & PLASTER	$467,691.09
093104	195	CERAMIC TILE	$180,610.33
096804	195	CARPET	$208,370.64
099104	195	EXTERIOR PAINTING	$72,930.00
099200	195	INTERIOR PAINTING	$140,893.57

SPECIALTIES DIVISION (10)			
Code	Project ID	Description	Cost
101000	195	SUNDRIES	$2,946.01
103000	195	FIREPLACES	$96,382.00
103100	195	FIREPLACE - MANTLE & HEARTH	$25,460.00
104300	195	EXTERIOR SIGNS	$4,052.56
105500	195	POSTAL SPECIALTIES	$3,270.60
108000	195	TOILET & BATH ACCESSORIES	$11,711.86
108700	195	SHOWER & TUB DOORS	$22,372.15
108804	195	MIRRORS	$21,334.00

EQUIPMENT DIVISION (11)			
Code	Project ID	Description	Cost
111510	195	PARKING GATES	$24,467.97
114501	195	APPLIANCES - LABOR	$16,071.39
114503	195	APPLIANCES - MATERIAL	$246,443.71
114801	195	ATHLETIC & REC EQUIP	$22,296.00

FURNISHINGS DIVISION (12)			
Code	Project ID	Description	Cost
123000	195	MFG CABINETS & CASEWORK	$246,140.00
125000	195	WINDOW TREATMENT BLINDS	$44,500.73

SPECIAL CONSTRUCTION DIVISION (13)			
Code	Project ID	Description	Cost
131530	195	WHIRLPOOLS	$18,212.65

CONVEYING SYSTEM DIVISION (14)			
Code	Project ID	Description	Cost
------------	195	--	$0.00

ELECTRICAL DIVISION (15)			
Code	Project ID	Description	Cost
154004	195	PLUMBING SYSTEMS	$674,723.39
154504	195	PLUMBING FIXTURES	$147,867.06
158000	195	AIR DISTRIBUTION	$620.00
158004	195	AIR DIST. SHEET METAL	$85,017.56

MECHANICAL DIVISION (16)			
Code	Project ID	Description	Cost
164004	195	ELECT SERVICE & DISTRIBUTION	$328,041.77
165003	195	LIGHTING FIXTURES	$102,718.83
165503	195	SITE LIGHTING	$5,392.73
167270	195	BURGLAR ALARM SYSTEMS	$4,800.00
167400	195	TELEPHONE INTERCOM SYSTEMS	$11,757.35

ENGINEERING FEES DIVISION (17)			
Code	Project ID	Description	Cost
171000	195	ARCHITECTS	$109,969.86
171100	195	MODEL	$2,461.00
171200	195	INTERIOR DESIGN	$16,424.67

ENGINEERING FEES DIVISION (17) continue....			
Code	Project ID	Description	Cost
172000	195	LANDSCAPE ARCHITECT	$20,925.05
172500	195	ENVIRONMENTAL CONSULTING	$6,891.25
173000	195	STRUCTURAL ENGINEERING	$10,927.00
173100	195	STRUCTURAL BUDGET REVIEW	$53,840.60
174000	195	MECHANICAL ENGINERRING	$17,980.81
175000	195	ELECTRICAL ENGINEERING	$10,017.04
176000	195	SOILS ENGINEERING	$10,407.29
177000	195	CERTIFIED PROFESSIONAL	$4,940.50
178000	195	LEGAL SURVEY -	$35,005.00

LAND FEES DIVISION (18)			
Code	Project ID	Description	Cost
180100	195	LAND	$4,656,154.31
181000	195	LAND FINANCING	$326,595.00
182000	195	LAND CARRYING - PONDEROSA	-$3,279.42
183000	195	PROPERTY PURCHASE TAX	$61,305.04
185000	195	LAND PROPERTY TAX	$246.79
186000	195	LAND APPRAISALS	$1,942.05

UTILITIES AND OTHER DIVISION (19)			
Code	Project ID	Description	Cost
191100	195	BUILDING PERMITS	$2,505.91
192000	195	LEGAL FEES	$27,103.26
193000	195	TAXES	$116,127.85
194000	195	INSURANCE	$48,023.82
196000	195	NWE HOME WARRANTY	$17,200.00
196500	195	CMHC FEES	$3,000.00
197200	195	WATER CONNECTION FEE	$29,624.51
197400	195	HYDRO CONNECTION FEE	$50,214.00
197500	195	TEL CABLE CONN FEE	$3,867.82
198000	195	OFFSITES	$264,901.78
199000	195	D.C.C.	$1,220,214.18

FINANCING FEES DIVISION (20)			
Code	Project ID	Description	Cost
201000	195	MORTGAGE FEE	$105,700.00
201100	195	QUANTITY SURVEYOR	$2,800.00

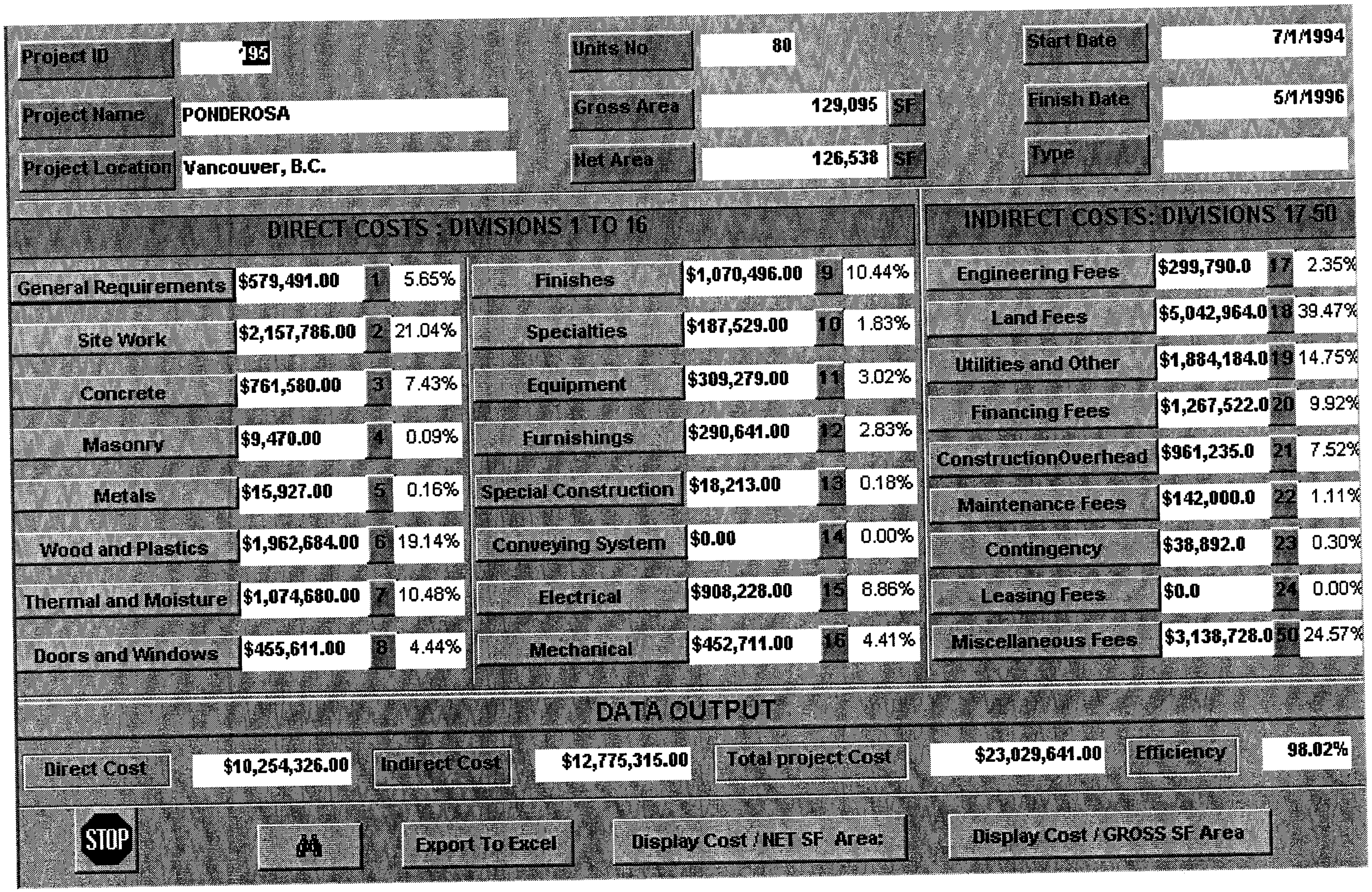
CONSTRUCTION OVERHEAD DIVISION (21)			
Code	Project ID	Description	Cost
211000	195	CONSTRUCTION OVERHEAD	$0.00
211500	195	CONSTRUCTION OVERHEAD -	$961,234.95

MAINTENANCE FEES DIVISION (22)			
Code	Project ID	Description	Cost
229021	195	Suites - maintenance	$142,000.00

CONTINGENCY DIVISION (23)			
Code	Project ID	Description	Cost
232100	195	CONTINGENCY MARKET	$38,891.50

LEASING FEES DIVISION (24)			
Code	Project ID	Description	Cost
240000	195	LEASING FEES	$0.00

MISCELLANEOUS FEES DIVISION (50)			
Code	Project ID	Description	Cost
509000	195	STRATA FEES	$154,089.96
509010	195	BROCHURES, GRAPHICS, STATION	$32,787.36
509020	195	SIGNAGE (OUTSIDE)	$79,456.59
509030	195	ADVERTISING	$273,577.75
509040	195	DISPLAY SUITE	$171,512.71
509050	195	SALES OFICE TELEPHONE	$8,546.59
509060	195	OFFICE SUPPLIES & SUNDRIES	$4,166.18
509070	195	CLEANING	$21,094.95
509090	195	LABOUR	$5,314.76
509100	195	COURIER	$661.17
509110	195	INTERNAL COMMISSIONS	$276,347.35
509120	195	EXTERNAL COMMISIONS	$206,648.58
509130	195	MISCELLANEOUS	$1,597.35
509140	195	PROPERTY TAX PONDEROSA	$60,826.64
509200	195	CUSTOMIZATION - MARKETING	$238,987.77
509300	195	MARKETING FINANCE -	$1,599,149.0
509360	195	MARKETING OVERHEAD DIRECT	$33.75
509450	195	NET RENTAL REVENUE	-$11,121.73
509500	195	LEGAL FEES	$15,051.56



Project ID	'95	Units No	80	Start Date	7/1/1994
Project Name	PONDEROSA	Gross Area	129,095 SF	Finish Date	5/1/1996
Project Location	Vancouver, B.C.	Net Area	126,538 SF	Type	

DIRECT COSTS : DIVISIONS 1 TO 16

General Requirements	$579,491.00	1	5.65%
Site Work	$2,157,786.00	2	21.04%
Concrete	$761,580.00	3	7.43%
Masonry	$9,470.00	4	0.09%
Metals	$15,927.00	5	0.16%
Wood and Plastics	$1,962,684.00	6	19.14%
Thermal and Moisture	$1,074,680.00	7	10.48%
Doors and Windows	$455,611.00	8	4.44%
Finishes	$1,070,496.00	9	10.44%
Specialties	$187,529.00	10	1.83%
Equipment	$309,279.00	11	3.02%
Furnishings	$290,641.00	12	2.83%
Special Construction	$18,213.00	13	0.18%
Conveying System	$0.00	14	0.00%
Electrical	$908,228.00	15	8.86%
Mechanical	$452,711.00	16	4.41%

INDIRECT COSTS: DIVISIONS 17-50

Engineering Fees	$299,790.0	17	2.35%
Land Fees	$5,042,964.0	18	39.47%
Utilities and Other	$1,884,184.0	19	14.75%
Financing Fees	$1,267,522.0	20	9.92%
ConstructionOverhead	$961,235.0	21	7.52%
Maintenance Fees	$142,000.0	22	1.11%
Contingency	$38,892.0	23	0.30%
Leasing Fees	$0.0	24	0.00%
Miscellaneous Fees	$3,138,728.0	50	24.57%

DATA OUTPUT

Direct Cost	$10,254,326.00	Indirect Cost	$12,775,315.00	Total project Cost	$23,029,641.00	Efficiency	98.02%

STOP

Export To Excel

Display Cost / NET SF Area:

Display Cost / GROSS SF Area